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PRELIMINARY TESTS OF PICATINNY ARSENAL DEVICE (LINEAR CUTTING CHARGE) AGAINST DYNAMICALLY FIRED AMMUNITION (S)

ELEVENTH REPORT ON PROJECT TB3-1224B

ARMOR TEST REPORT AD-1228

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APillersdorf/em/29175
27 March 1956

PRELIMINARY TESTS OF PICATINNY ARSENAL DEVICE (LINEAR CUTTING CHARGE) AGAINST DYNAMICALLY FIRED AMMUNITION (S)

ELEVENTH REPORT ON PROJECT TB3-1224B

ARMOR TEST REPORT AD-1228

DATES OF TEST: AUGUST 1954 TO JUNE 1955

OBJECT

To investigate the performance of and evaluate first models of explosive charges designed for use as an active defense against shaped charge missiles.

SUMMARY

Thirty-four Picatinny Arsenal Devices were detonated against various anti-tank projectiles in flight during dynamic firings of these projectiles against target armor. Frequent defeat of projectiles, under special conditions, was achieved. Picatinny Arsenal Devices were also detonated for high speed photography and calibrating purposes.

CONCLUSION

The device as tested offers considerable promise as a protective measure for armored vehicles, provided an adequate sensing and triggering mechanism is developed, and tactical limitations are overcome.

RECOMMENDATION

Development and application studies, including sensing and triggering, should be continued, with special emphasis on increasing the versatility and effectiveness of the liner fragments.

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I. INTRODUCTION:

A. DISCUSSION

1. On 28 July 1953, a conference on Defense Against Shaped Charges was held at the Ballistic Research Laboratories, APG. This conference resulted in the formation of the Ordnance Corps Committee on Defense Against Shaped Charges.* At this same conference, a unique method of defense against shaped charge missiles, evolved by Picatinny Arsenal personnel, was described. In this method, a lined explosive charge,**triggered by an incoming projectile, produces a sheet of fragments in a plane roughly normal to the trajectory of the missile. These fragments strike the HEAT shell body and so damage it that the shell loses its penetration capabilities. The application of this device then envisioned was the setting of a series of such charges on the stowage boxes, fenders and turret periphery of a tank, as necessary.

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2. The lined explosive charge demonstrated initially was referred to as a "linear cutting charge," after the British terminology. It was described more fully at the first meeting of the above-mentioned Committee on 25 September 1953.

3. At the meeting in September 1953, the charge model was described by Picatinny Arsenal as approximately eight inches long, carrying a little over a pound of explosive, with a T18 detonator and annular booster near each end, making for two-point initiation. In the first tests by Picatinny Arsenal, seven 3.5 inch HEAT M28A2 rockets were fired at armor plate, first striking a pair of aluminum foil electric-detonator triggering screens in front of the plate. These screens, on short-circuiting, permitted the detonator system to initiate the charges. No 3.5 inch rocket round penetrated more than three-fourths of an inch of the armor against which it was fired.

4. The suggestion was made by the D&PS representative at this meeting that such a device was potentially even more valuable against other missiles than HEAT. This was predicated on two possibilities:

a. Effective breaking up or cracking of a large caliber armor-piercing shot might be achieved by the impact of liner fragments on the projectile body. This aspect was investigated in the tests to be described.

b. The impact of a liner fragment of sufficient momentum might deflect or upset the target missile by an amount sufficient to prevent complete penetration of the target armor. An elementary study of this aspect indicated that upsetting a large caliber projectile of the AP or AP HE type by fifteen degrees (a conservative guess of the amount necessary to degrade the penetration capability of typical AP projectiles fired against oblique armor) requires an inordinately large fragment momentum. A limiting condition is the distance the missile must travel, before it strikes the target armor, after being hit by a liner fragment.

5. a. A basic limi ation of the method of defense by this explosive device is the necessity for a reliable and accurate sensing and triggering system. One

* Ref.: Letter from ORDTB, File No. 334/924, APG 337/900
** See sketch in Appendix B

reason given for the relatively slow development of the charge is that without an automatic, quick-acting, sensing and initiating system, it is relatively useless for its intended purpose.

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b. Considerable progress has been made, however, in the direction of developing a sensing and triggering system, under project DASH DOT, Ordnance Project No. TA3-5204. Under technical supervision of the Picatinny Arsenal, the United Shoe Machinery Corporation has developed an electronic mechanism system for the purpose described above.

c. The following is a description of the system provided by the contractor in a progress report.

A method using C.W.X. band radar has been tentatively adopted for the detection of attacking missiles. Missile velocity is determined by the doppler frequency produced by the impact of the transmitted energy on the approaching missile. The range of missile velocities involved requires the production of a time delay which increases as the missile velocity decreases, in order that all missiles may be in the same vertical plane at the instant of detonation of the linear charge which is used to defeat the missile. The delay required for all missiles between 200 and 3000 feet-per-second velocities has been worked out, theoretically resulting in all missiles being in the same vertical plane $\pm$ 1.43 inches over a vertical distance of 5 feet. Various methods of developing the required delay have been explored and a breadboard model of a simple and reliable method has been constructed. The delay available has been extended to 3800 microseconds maximum, to include low velocity missiles arriving at extreme angles of obliquity. The radial velocity of a 200 feet per second missile may be only 67 feet per second, producing a doppler frequency of some 1360 cycles per second. A "missile simulator" in which Styrofoam cylinders are propelled along a plexiglass tube has been constructed to enable preliminary tests to be run in the laboratory. Missile velocities in excess of 350 feet per second have been obtained in the "simulator" and velocities up to 500 feet per second should be possible with increased air pressure.

d. A description of the instrumentation used is provided in the January 1955 progress report by the same agency.

e. A test with the breadboard model sensing dynamically-fired artillery missiles was described at the meeting of the Ordnance Corps Committee on Defense Against Shaped Charges on 1 Nov 1955. The test results were generally satisfactory.

f. A second limitation of the device in its present form is that connected with exposed mounting on a vehicle. With the apex of the liner in normal position, so that fragments can be projected upward, the device may accumulate mud, dust and snow in the exposed cavity. A brief, inconclusive test of the PAD was conducted in conjunction with the calibration and high speed movie firings to investigate this limitation. Some reduction in fragment energy was noted with one charge.

6. Countermeasures that might be employed against a successful application of a radar-controlled PAD* system to a vehicle would depend to a large extent on the performance of the sensing system and the location of the PAD.

a. If the charges were mounted close to the tank surfaces, and aimed vertically, it might be feasible for the enemy to use and attacking HEAT missile which attempted to detonate before the PAD did. A large diameter (6 in. and up), long-ogived, HEAT round, performing better at a long standoff than conventional ones, might be adequate for penetrating the tank defended by PADs, in the arrangement described.

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b. A more complex round might incorporate the above features and a proximity fuse as well.

c. The above speculative anti-PAD missile designs add additional support to the Proving Ground's interest in the design and development of PAD type devices for other applications (i.e. anti-AP, anti-HE shell, anti-personnel, anti-mine).

d. Finally, while beyond the province of this report, it is not overlooked that PAD type devices may prove feasible as protective measures in some US Air Force and US Navy materiel. Air-to-air defense against chemical energy missiles is an application worthy of serious consideration and extensive development.

B. REFERENCES

1. Ltr, ORDTB 334/924, APG 337/900. Subject: Ordnance Corps Committee on Defense Against Shaped Charge Program.

2. Memorandum from Director BRL to Director, D&PS, 2 August 1954.

3. Memorandum from Director BRL to Director, D&PS, 3 November 1954.

4. Monthly Progress Reports on Ordnance. Project TA3-5204 (DASH DOT) by Research Division, United Shoe Machinery Corp.

5. Minutes of the Ordnance Corps Committee on Defense Against Shaped Charge Weapons, November 1955.

* The term PAD (Picatinny Arsenal Device) was proposed by the D&PS and accepted by the Picatinny Arsenal representative at a Committee meeting.

II. DESCRIPTION OF MATERIEL

A. Some modification of the first demonstration model of the Picatinny Arsenal device was effected by the Terminal Ballistics Laboratory, BRL. A single point initiator (M36) was substituted for the twin initiators hitherto used.

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1. A flash radiograph of the fragment pattern of such a charge is provided in Vol. I, No. 2 of the Ordnance Corps Shaped Charge Journal, Oct. 54, (Pages 276-277).

2. This radiograph shows the divergence and critical curvature of a single-point initiated sheet jet. A 3-point-initiated charge with an essentially straight front, had interacting jets where the main fronts met at the liner. This charge had a ninety degree wedge angle with a 1/16 inch copper liner. For the dynamic firing tests described herein, the TBL- BRL versions of the PAD were used. A sketch of a typical PAD is provided in Appendix B. The devices used were ten inches long and loaded with 1.67 lbs. of C3. In section the steel or copper liner resembles the letter M. The interior angle was usually large, ranging from 115 to 165 degrees for different liner designs and materials.

B. Target armor for the dynamically-fired projectiles was rolled homogeneous armor of varying thicknesses and obliquities. Thickness and obliquity were combined so that the projectile could defeat the armor unless degraded by the PAD fragments. Major items used are listed below:

PROJECTILE	WEAPON	ARMOR	OBLIQUITY
90mm AP, T33E7	Gun, M3	4 inches R.H.	15°
90mm HEP-T, T142E3	Gun, T119	2 inches R.H.	55°
106mm HEAT, T119E11	Rifle, M70	4 inches R.H.	30°

III. DETAILS OF TEST

A. PROCEDURE

1. For the major test phases, i.e., defeat of dynamically fired missiles, the target armor was placed in plate butts to provide obliquity in the vertical plane. The charges (PADS) and triggering screens were then positioned on the ground, usually a few feet from the armor. These distances were changed as test requirements dictated. The vertical and the horizontal distances between the charge and the trajectory of the attacking projectile were varied for different projectiles.

2. When the projectile was fired at the target armor, it passed through and short-circuited a pair of closely spaced aluminum foil or wire mesh screens. This permitted initiation of an M36 electric detonator which in turn initiated the PAD. A successful PAD was one which prevented complete penetration of the armor by the attacking (target) projectile.

3. When test results dictated, fastax films were taken to obtain data on the behavior of the PAD fragments and on the target projectile.

4. To obtain data on PAD fragment velocity and penetration characteristics, special detonation tests were conducted in a final test phase. PADs were detonated so that fastax films of fragments striking mild steel plate could be made. The time interval between the detonation and the flash caused by a fragment striking the target was computed from the film. Since the charge to plate distance was known, the velocity of the fastest liner fragments was determined.

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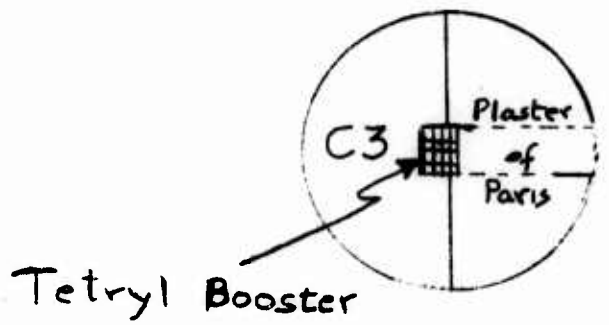
5. The PAD liner fragments were checked for depth of penetration into mild steel, both with and without a filling of mud in the liner wedge. It appeared that such penetration was limited for the weight of explosive used. Accordingly, a crude comparative fragmentation test was devised.

a. Locally available steel pipe nipples, 2 inches ID by 6 inches long, and 2 1/2 inches ID by 10 inches long, were half-filled, axially, with plaster of paris. A hole was drilled in the nipple wall at mid-length, thru the inert filler, to house a tetryl pellet. Explosive C3 was then pressed into the remaining semi-circular segment of the pipe, for its full length. In section, the pipe looked like this:



B. RESULTS

1. Detailed firing data and results for the PAD vs 90mm AP T33E7 shot and vs the 106mm HEAT T119E11 are contained in F.R. No. Ar-20352, a copy of which forms Appendix C.

a. With steel-lined PADs eighteen inches below the trajectory, 90mm AP T33E7 projectiles were defeated four times in four, at projectile velocities of the order of 2050 fps. The defeated projectiles were cracked or broken by liner fragments as shown by one smear type photograph, APG B2167, in Appendix C; when the velocity of the attacking T33E7 projectile was increased to 2500 fps, the projectile defeated the target armor in the limited firings conducted. The exact interaction between liner fragments and successful projectile is not known. A change in liner design or orientation may be adequate for defeating the higher velocity projectile. (For attack at 15° obliquity by 90mm AP T33E7, the ballistic limit velocity of a 4-inch rolled homogeneous armor plate like the target plate is usually of the order of 1700 fps).

b. With copper-lined charges at the same distance (18 inches below and 4 inches off center of the trajectory), several recoilless rifle rounds, 106mm HEAT, T119E11, were defeated. At 29 inches below and six inches off center, and at forty-two inches below and nine inches off center, the PAD was successful. One round was fired for each condition described.

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c. Several of the other rounds fired in this 106mm T119E11 series were of dubious quality, however. This was evidenced by a fuze failure on a final T119E11 fired as a check. Without a PAD in position to attack it, this last round broke up on the face of the target armor plate without proper functioning.

2. Detailed firing data and results for the target 90mm HEP-T T142E3 projectiles, fired at velocities of the order of 2320 fps, are contained in Appendix D. Copper lined charges with included angles of 115°, 140° and 165° were used. A summary of results follows:

PAD LINER ANGLE	VERTICAL STANDOFF (PAD below Trajectory)	RESULTS
115°	1 at 18 inches	Projectile defeated
	1 at 30 inches	Projectile defeated
	1 at 45 inches	Projectile not defeated
140°	1 at 18 inches	Projectile defeated
	3 at 30 inches	Projectile defeated
	6 at 45 inches	Projectile not defeated
	2 at 60 inches	Projectile not defeated
165°	1 at 30 inches	Projectile not defeated

3. It appears then that vertical distances greater than thirty inches are too much for the PAD, as tested, against 90mm HEP-T, T142E3.

4. When it seemed that fragment energy fall-off or some similar factor was critical over a short distance (i.e., from 30 to 45"), fastax films to obtain liner fragment velocity data were taken. Inspection of films indicated that a few of the fastest liner fragments were of approximately uniform velocity (11,000 fps) over a six foot distance. Velocity data for most liner fragments was not obtainable by standard high speed photography methods.

5. Static detonation of the charge for fragment penetration data indicated fairly limited spread and penetration. (See Appendix E and Photos). Comparable penetrations and wider spread were obtained using locally available 2 1/2 inch galvanized steel pipe nipple and lesser explosive charge weights.

6. When the wedge or cavity of one charge was filled with moist soil, a fall-off in fragment penetration was observed.

C. OBSERVATIONS

1. a. The defeat of attacking chemical energy ammunition (HEAT, HEP-T) resulted from high order detonation of the explosive charge. This, in turn, resulted from copper-liner fragment penetration of the shell body.

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b. A high order detonation of an incoming missile may be undesirable* for the vehicle being defended. Attempts to defeat chemical energy ammunition by lower energy particles may be desirable from this standpoint as well as from the standpoint of reducing the amount of explosive filler in the defending charge.

2. The maximum vertical distance required between incoming missile and liner varied with each type of missile. For defeating kinetic energy rounds, a shorter distance may be required. If this is so, a determination of the major missile targets should be made. This re-evaluation of the mission of PAD type devices is necessary because of the possibility of specially designed ammunition of the HEAT type which might frustrate such a device (See IA-Discussion).

D. OBSERVERS

In addition to D&PS and BRL personnel directly connected with these firings, the following were present for some phases of the HEP-T firings:

Mr. Paul Willner - Picatinny Arsenal

Mr. J. L. Minto - United Shoe Machinery Corp.

IV. CONCLUSIONS

A. The PAD (Linear Cutting Charge) as tested offers considerable promise for protection of armored targets against chemical energy ammunition of the HEAT and HEP type.

B. The device also offers considerable, if not superior promise for use against high explosive shell, armor piercing projectiles and similar artillery ammunition.

C. As tested, the performance against 90MM AP ammunition fell below that against HEP-T and HEAT.

D. The tactical performance of such a device may be limited by environmental conditions such as terrain, snow, dust, etc.

E. The test data does not permit selection of an optimum liner material or configuration until tactical objectives and limits of performance have been established.

* Large caliber HE filled shell may cause serious blast damage on the tank exterior. Fragments resulting from a high order detonation would also be a serious damage threat. A low-order detonation, or mere shell break-up, is therefore preferable.

V. RECOMMENDATIONS

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A. The development of explosive and liner combinations should be extended to provide a determination of the most effective system.

B. The application to defeat foreign HEAT and kinetic-energy artillery ammunition should be stressed in future development.

C. Increased versatility of the device should be a major objective in future design, with some attention to anti-personnel utilization.

D. Tests to determine operational suitability on a moving vehicle should be initiated. Performance under varying weather and terrain conditions should be investigated.

E. Specific military characteristics should be made the basis of future design. These characteristics should take into consideration the limitations and potential versatility of the charges tested as described in this report as well as such obvious considerations as safety of tank crews and tank-accompanying infantry.

Arthur Pillersdorf
ARTHUR PILLERSDORF
Eng. Ordnance

Benjamin S. Goodwin
BENJAMIN S. GOODWIN
Assistant Director for
Engineering Testing
Development & Proof Services

Herbert L. Rosenberg
HERBERT L. ROSENBERG
Chief, Terminal Ballistics
Division

SECRET

APPENDICES

APPENDIX A - Correspondence

APPENDIX B - Sketch of PAD

APPENDIX C - Firing Record Ar-20352

APPENDIX D - Firing Data and Results - PAD vs 90mm HE-P

APPENDIX E - Witness Plate and Fragmentation Data

APPENDIX F - APG Photographs Nos. B5968-B5973 inclusive.

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APPENDIX A

CORRESPONDENCE

1. Interoffice Memo from Director, BRL to Director, D&PS dated 2 August 1954 with 1st Indorsement dated 19 October 1954
2. Interoffice Memo from Director, BRL to Director, D&PS dated 3 November 1954
3. Letter, File APG (S) 471/31, 00 4S-/8892
4. Teletype ORDBB-TR1 TT8696 22706 7 1954

SECRET

Request for Firing of 90mm Kinetic Energy Rounds and 105mm Recoilless HEAT Rounds

1st Ind Mr APillersdorf/hlc/23229

SECRET

Director, Development & Proof Services, 19 October 1954

TO: Director, Ballistic Research Laboratories

1. The dynamic firing test requested has been completed. Firing data and results are contained in Firing Record AR-20352, copies of which are to be forwarded to both Weapons Systems and Terminal Ballistics Laboratories.

2. As pointed out by the D&PS representative at meetings of the Committee on Defense Against Shaped Charges the Picatinny Arsenal Device offers particular promise against non-HEAT rounds. The 90mm AP T33E7 round is the most severe test of the device. At very low remaining velocities (2050 fpr or so), the round was totally defeated four times in four. At 2500 fps or so, the charges provided by TBL were unsuccessful in stopping the round. Since appropriate development testing of this device has been so limited to date D&PS has proposed to test various modifications and applications of this device, particularly against foreign ammunition. Replies from ORDTA, ORDTB, and ORDTT are presently awaited.

3. In view of the SECRET classification of results on this project by Picatinny Arsenal, this correspondence is being upgraded accordingly.

T. F. COLLERAN

COPY OF CONFIDENTIAL OFFICE MEMORANDUM FOR FILE

Mr Kirkpatrick/ccw/22261
2 August 1954

TO : Director, Development & Proof Services

FROM : Director, Ballistic Research Laboratories

SUBJECT: Request for Firing of 90mm Kinetic Energy Rounds and 105mm Recoilless HEAT Rounds

SECRET

1. In connection with work on the defense against shaped charge weapons a method has been proposed by people at Picatiny Arsenal and has been tested to some extent by members of the Terminal Ballistics Laboratory. However, to determine the full value of this type of defense it will be necessary to fire full scale dynamic rounds.

2. This form of defense consists of a line charge, fired by electronic means, to damage the shell before it arrives at the armor. Conversation with Mr. Cronman of TBL indicates that charges are available and that they can be prepared for these tests. It is desirable that the results of these tests be available for the next meeting of the Committee on Defense Against Shaped Charges 26 August 1954.

3. The test desired would consist of 10 rounds of 90mm AP fired into an armor target protected by this device. The other test would consist of 10 rounds of 105mm HEAT ammunition fired from the 105mm recoilless rifle. The armor for this second condition would be identical with that for the first test. It is desired that high-speed motion pictures be made of the terminal effects of these firings.

4. It is requested that 10 rounds each of the kinetic energy and the HEAT rounds be fired. Necessary material and labor will be charged to Project TB3-1224B, W.O. 962-002-00.

5. It is further requested that these Laboratories be notified of the time of the firings in order that an observer may be present.

s/ Herbert R. Dichtenmueller
HERBERT R. DICHTENMUELLER
Lt Col Ord Corps
Asst to Director
BRL

COPY

OFFICE MEMORANDUM - UNITED STATES GOVERNMENT

THRU : Chief, Weapon Systems Laboratory
Chief, Terminal Ballistics Laboratory

ELKirkpatrick/ah/22261

DATE: 3 November 1954

TO : Director, Development and Proof Services

SECRET

FROM : Director, Ballistic Research Laboratories

SUBJECT: Test of HEP vs Line Charge

1. It is requested that 90mm HEP ammunition be fired to determine an effective method of employing the line charge for the defeat of this type of ammunition as per conversations between Mr. E. L. Kirkpatrick of WSL, Mr. Kronman of TBL and Mr. Pillersdorf of D&PS.

2. Twenty-five lot PA 188-8 HEP projectiles will be allocated for these tests under Project TB3-1224B.

3. The line charges with their sensing circuits will be supplied by the TBL of BRL at the time of the tests.

4. It is requested that the armor arrangement for these tests be such that it would be defeated 100% of the time by the 90mm HEP round when a defense mechanism is not used. The arrangement to be used will be with concurrence of TBL, WSL and D&PS representatives.

5. It is requested that spalls resulting from any unsuccessful line charge defenses be recorded with their weight, description and photographs.

6. The tests will be interrupted at any time the BRL deems necessary for revision of the sensing device.

7. It is requested that 10 rounds be fired at a condition before it is credited with successful defeat of the round.

8. It is requested that high speed motion pictures be taken of the engagement of the round with the target.

9. It is requested that photographs be taken of the target arrangement before and after the tests.

10. The results of these tests will be classified "SECRET".

11. It is requested that the BRL be notified at least 72 hours prior to the firing of these tests so that Picatinny Arsenal and the United Shoe Machine Company, under contract to Picatinny Arsenal, may be notified.

12. The priority of this project is 1A.

/s/ E. N. Kirsten
/t/ E. N. Kirsten
Lt. Colonel, Ord Corps
Asst. to Director
Ballistic Research Laboratories

SECRET

17

Mr APillersdorf/hlc/23229

APG(S)471/31
00/4S-18892

ORDBG-DPS-AA

SUBJECT: Dynamic Tests of Picatinny Arsenal Device (Cutting Charge)

TO: Chief of Ordnance
Department of the Army
Washington 25, D. C.

ATTENTION: ORDTT

SECRET

1. The efficacy of the Picatinny Arsenal Device in defeating kinetic energy and HEAT projectiles has been demonstrated by a brief firing test of a modified charge provided by Terminal Ballistics Laboratory, Ballistic Research Laboratories. Detailed results are reported in Aberdeen Proving Ground Firing Record Ar-20352.

2. Given below is a summary of results obtained for the following projectile types when attacked by the modified Picatinny Arsenal Device:

a. Four rounds of 90mm AP T33E7 Shot were unable to penetrate a 4" armor plate at 15° obliquity protected by a cutting charge; the striking velocity was approximately 2050 fps whereas the ballistic limit velocity of the plate alone was approximately 1700 fps.

b. Four rounds of 90mm AP T33E7 Shot fired at approximately 2500 fps were able to completely penetrate the same 4" armor plate protected by a cutting charge.

c. Six rounds of 106mm HEAT ammunition (the T19E11 Shell) fired at approximately 1600 fps were unable to produce penetrations greater than 2" in the armor plate target protected by a cutting charge.

3. Since the 90mm AP projectile was selected as the most severe test projectile for the cutting charge, the potential of this type of device in an improved form should not be overlooked in other respects:

a. For use against HE shell and composite shot (HVAP, AP-DS, etc.) as well as against Soviet AP-HE ammunition.

b. As an equivalent of appreciable armor thickness; while the 90mm AP projectiles fired at 2500 fps were not totally defeated, they may have been upset or degraded so that the actual ballistic limit velocity against the target plate would have been appreciably higher than the limit velocity obtained by firing against an "unguarded" plate.

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ORDBG-DPS-AA
SUBJECT: Dynamic Tests of Picatinny Arsenal Device (Cutting Charge)

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4. The cutting charges provided for this test had liners of steel for use against the AP projectiles, and of copper for use against the HEAT ammunition. Results of static detonation tests conducted by Terminal Ballistics Laboratory and reported verbally by their representatives show that steel liners in this type of charge cause more severe damage to AP projectiles than do copper liners. Apparently this is because the larger fragments from the steel liner are able to more effectively damage or break up the heavy body of the AP projectiles. Steel liners should also be effective against HEAT ammunition although because of the thin wall of such ammunition copper liners have been found sufficiently effective. Testing of materials to determine what materiel will furnish the optimum liner for effectiveness against all types of attack has of necessity been limited to date but needs to be explored fully to establish definitely the performance which can be expected from cutting charges. Tests of liner materials should include various types of steels, steel-copper bimetallic or amalgam liners, cast iron and possibly titanium as liner materials.

5. Since the referenced test program has been completed, no further testing can be planned until new directives are received.

a. Development and Proof Services has received a copy of a directive from the Detroit Arsenal, the original being in Office, Chief of Ordnance, ORDTT; it is recommended that this directive be forwarded for action by Development and Proof Services.

6. It is recommended that Development and Proof Services be authorized to investigate the following:

a. Defeat of HE, HVAP, AP-DS, and Soviet PA-HE ammunition by cutting charges.

b. Behavior of cutting charges against higher velocity kinetic energy (AP, APC) and HEAT rounds, this to be given high priority.

c. Testing of a cutting charge incorporating desirable features of the "Claymore Device" for anti-personnel use. This would make for a more versatile and logistically desirable item of ammunition: A dual-purpose tank-mounted or hand-carried grenade.

d. Applications of modified forms of the charge as an anti-tank mine and as a device to defeat anti-tank mines.

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FM CO PICATINNY ARSENAL DOVER NJ

TO CG ABERDEEN PG MD

DA GRNC

FOR ORDBG-AA-DPS PLESS FROM ORDBB-TR1 TT8696 WILLNER SGD CARSON YOUR 22706 AND SUBSEUUENT FONECON BETWEEN PILLERSDORF AND WILLNER CDR DR B A LLOYD AND MR PAUL WILLNER WILL ATTEND TEST FIRINGS 7 DEC 1954 IN CONNECTION WITH TANK DEFENSE PD IN ADDITION A MAXIMUM OF 4 PERSONNEL FROM UNITED SHOE MACHINERY CORP WILL ATTEND IN CONNECTION WITH CONTR P-49

CFN ORDBG-AA-DPS ORDBB-TR1 TT8696 22706 7 1954 4 P-49

03/1856Z

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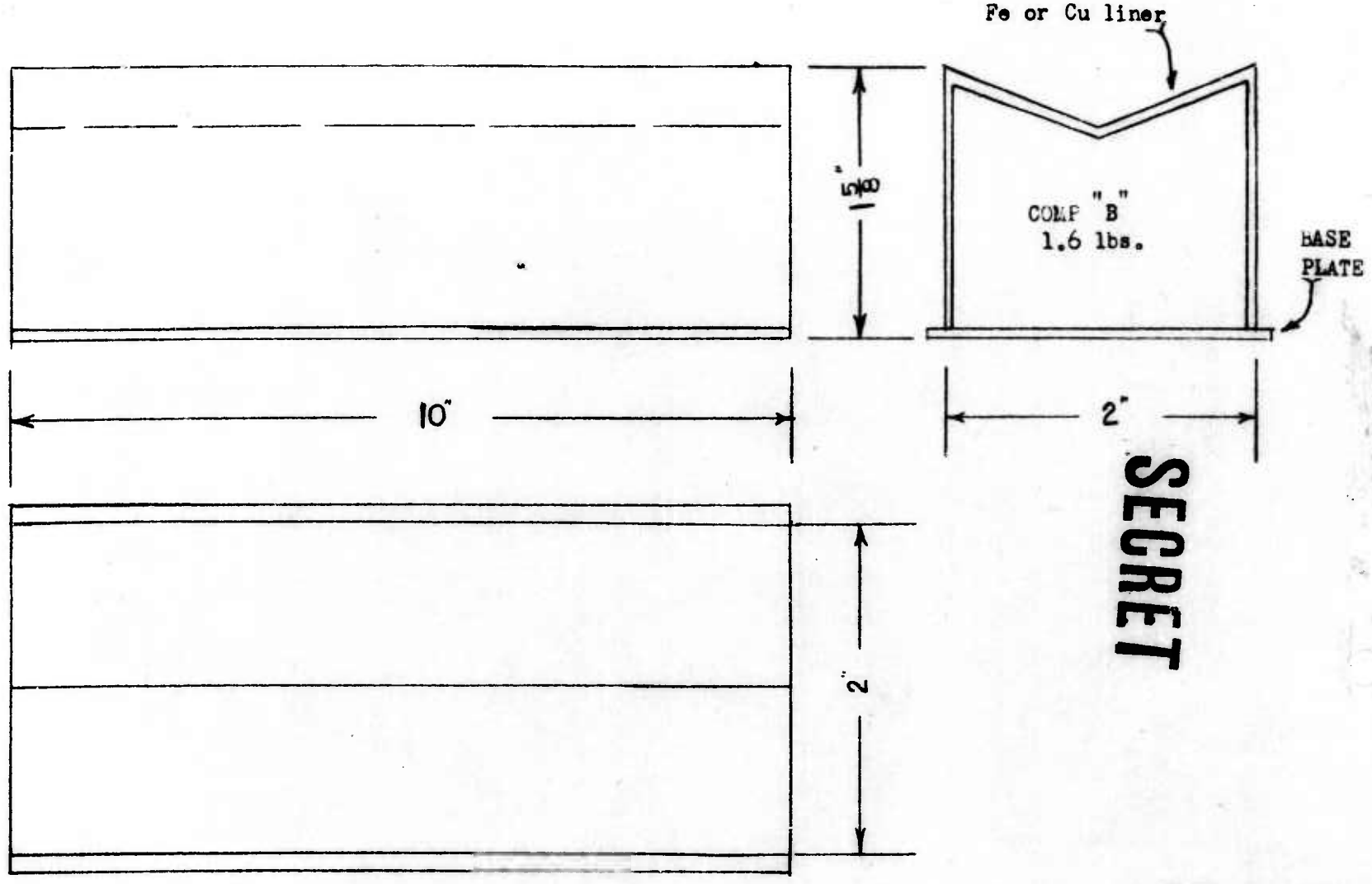
APPENDIX B

Sketch of Picatinny Arsenal Device

(Linear Cutting Charge)

PICATINNY ARSENAL DEVICE (LINEAR CUTTING CHARGE)



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APPENDIX C

Firing Record AR-20352

AMXRD-TP
AR-20352

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DEVELOPMENT AND PROOF SERVICES
ABERDEEN PROVING GROUND, MARYLAND
FIRING RECORD

OBJECT OF TEST: To Test The Effectiveness of a Special Picatinny Arsenal Device (Line Charge) in Defeating 90mm AP and 106mm HEAT Ammunition.

FIRING RECORD NO: Ar-20352
SHEET 1 OF 3
DATE OF TEST: 18 August '54 thru 25 August '54
REFERENCE: Memorandum dated 2 August 1954 from Director, BRL, to Director, D&PS

DEVELOPMENT PROJECT NO.: TB3-1224B

SECRET

W. O. : 962-002-00

APG 353.4/1965

MATERIAL

Rolled Homogeneous Armor Plate No. 11424C1, 4" x 65" x 90", 329BHN
Rolled Homogeneous Armor Plate No. 11425A, 4" x 65" x 90", 324BHN

AMMUNITION - Henry T113.

1. Shell, 106mm, HEAT, T119E11 (M344), Ammunition Lot No. PA-E-12356.
2. Shot, 90mm, AP T33E7, Ammunition Lot No. RTQ 1-3.
3. Picatinny Arsenal cutting charge (Line Charge):-Modified charges provided by TBL, BRL. Description: BRL Model 8, loaded with 1.6 pounds of Comp. B; dimensions:-10" long, 2" wide, 1 5/8" high with 140° "vee" shaped slot cut longitudinally into one of the 10" x 2" surfaces. Either a steel (0.062" thick) or copper (0.065" thick) liner was assembled into the slot. See Inclosure No. 3 for a sketch of the Line Charge.

FACILITIES

Gun, 90mm, M3, No. 6171, with Tube No. 2597.
Recoilless Rifle, 106mm, T170E1, No. 166, with Tube No. 6115.

DESCRIPTION OF TEST SETUP

The target armor, a 4" x 65" x 90" RH Armor plate, was leaned against the front of the plate butts, tipped back from the vertical. The Line Charge and triggering screens were then positioned on the ground a few feet in front of the target plate which was some 150 feet from the gun. An M-36 detonator placed in the Line Charge was connected to one of the screens, and the screens energized by putting a 1200 volt D. C. power supply across them. A projectile passing through the screens completed the triggering circuit, setting off the M-36 detonator and the Line Charge. Copper mesh screens were used for the 90mm Shot, while thin aluminum foil strips were used in the screens when firing the sensitive 106mm HEAT shell to avoid fuze initiation.

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RESULTS

1. 90mm AP T33E7 Shot

a. Five rounds of 90mm AP T33E7 Shot were fired against the four inch plate at 15° obliquity. The striking velocity of approximately 2050 fps was some 300 fps above the estimated ballistic limit of the plate. Steel liners were used in all charges tested against the 90mm Shot.

(1) The Line Charge cutting fragments missed the first 90mm round (test round no. 3); the result was a complete penetration of the plate.

(2) Each of the next three rounds (test rounds nos. 4, 5, and 6) was struck by the cutting fragments of the Line Charge and was unable to penetrate the target; a 6" diameter scoop of 1" to 1 1/4" depth was produced by each round.

(3) A smear type photograph (see APG Photo B2167) was made of one round. As shown by the photo, Line Charge fragments have succeeded in breaking the projectile. The entire ogive has been broken off.

b. Four rounds of 90mm AP Shot (test rounds nos. 7, 8, 9, and 10) were fired at a velocity increased to approximately 2500 fps, with the armor at 15° obliquity. Each round made a complete penetration of the target. The effect of the Line Charge fragments on these rounds is unknown since no high speed motion pictures were obtained.

2. 106mm Shell, HEAT, T119E11 (M344)

a. Ten rounds of 106mm recoilless HEAT ammunition were fired at approximately 1600 fps with the target plate at 30° obliquity. Copper liners were used in the Line Charges supplied for this phase.

(1) Six 106mm rounds (test rounds nos. 1, 2, 3, 4, 6, and 7) were evidently struck by the Line Charge fragments; the effect of these on the target consisted, in each case, of fragment gouges and small jet penetrations (0" to 2½") of the armor.

(2) Two rounds (test rounds nos. 5 and 9) apparently were missed by the main fragments of the Line Charge. Each of the two rounds completely penetrated the target and produced residual penetrations of approximately 2" in a vertical back-up armor plate placed eleven feet behind the target.

(3) One round (test round no. 8) evidently was missed by the main fragments of the Line Charge and also failed to function by fuze action. This round detonated during crush-up against the plate without formation of a jet. The sole effect on the target plate was a 7" diameter dent, approximately 1/4" deep.

(4) One calibration round (test round no. 10) was fired without use of the Line Charge. It failed to function by fuze action and detonated during crush-up without formation of a jet. Results were identical to those of Round 8.

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FIRING RECORD NO. Ar-20352
SHEET 3 OF 3

DETAILED RESULTS OF TEST

Inclosure 2 provides round-by-round firing data and results.

OBSERVERS

Other than BRL and D&PS personnel conducting the test, no observers were present.

APPROVED:

BENJAMIN S. GOODWIN
Chief, Arms & Ammunition

W. C. PLESS
Chief, Armor Branch

J. C. GILLETT
Lt., Ord Corps
Proof Officer

INCLOSURES:
1. Distribution
2. Firing Data
3. Description of Triggering System & Line Charge Sketch
4. APG Photos B2054, B2055, B2167

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FIRING RECORD NO. At-20352
INCLOSURE 1

DISTRIBUTION

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FIRING DATA

90mm AP T33E7 SHOT

Test Setup: Target plate No. 114401; gun to target distance of approximately 150 feet; Line Charges with steel liners.

Date & Rd. No.	Distance--Screens to Plate	Distance--Line Charge to Plate	Distance--Line Charge is below line/flight of projectile	Distance--Line Charge Center is off-center from line/flight of projectile	Results (All dimensions of plate damage given as height by width.)
18 August Rd 1	Conditioning Round				Complete penetration of plate: face: scoop, 7" x 5¾"; back: exit hole, 9" x 8½"; 100% back spall. Plate obliquity: 14°; Striking velocity: 2001 fps.
18 August Rd. 2	Conditioning Round				Partial penetration of plate: face: scoop, 10" x 6¼", 3½" deep; back: Bulge, 10½" x 9½" with 20" circular crack around upper bulge circumference. Plate obliquity: 30°; Striking Velocity 2085 fps
18 August Rd. 3	39 3/4"	35 1/4"	18"	4"	High speed motion pictures indicate Line Charge missed projectile. Complete penetration of plate: face: crater, 6" x 6"; back: exit hole, 8" x 9 1/4"; 100% back spall. Plate obliquity 15°; Striking velocity: 2085 fps.
19 August Rd. 4	39"	42"	18"	4"	Projectile hit by Line Charge. Partial penetration of plate: face: scoop, 6" x 6", 1¼" deep; back: slight bulge, 4" diameter. Plate obliquity: 15°; Striking Velocity 2026 fps.

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Firing [redacted] Cont

19 August Rd. 5	39"	41"	18"	4"	Results identical with round four. Plate obliquity: 15°; Striking Velocity: 2070 fps.
19 August Rd. 6	84"	86 1/2"	18"	4"	Results identical with round four. Plate obliquity: 15° Striking velocity: 2060 fps.
19 August Rd. 7	84"	86 1/2"	18"	4"	Line Charge effect on projectile unknown. Complete penetration of plate: face: crater, 7" x 7" rear: exit hole, 11" x 12¼"; 100% back spall. Plate obliquity: 15°; Striking Velocity: 2485 fps.
19 August Rd. 8	40"	40"	18"	4"	Complete penetration of plate: face: crater, 6 1/2" x 6 1/2" back: exit hole, 8 1/4" x 9 1/2"; 95% back spall. Plate obliquity: 15°; Striking Velocity: 2489 fps.
20 August Rd. 9	40"	44"	12"	4"	Complete penetration of plate: face: crater, 7" x 6¼" rear: exit hole, 6" x 4½"; 10% back spall. Plate obliquity: 15°, Striking Velocity: 2495 fps.
20 August Rd. 10	40"	47"	12"	4"	Complete penetration of plate: face: crater, 7" x 6¼" rear: exit hole, 8 ¾" x 9 ¾"; 100% back spall. Plate obliquity: 15°; Striking Velocity: 2496 fps.

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20 August Rd. 11	28'	28' 3"	18"	"	This round fired with target set back to obtain "smear type" photograph. Striking Velocity 2107 fps. Camera indicates that the projectile nose was fractured by fragments of line charge (see APG photo B2167). See APG photo B2055 for effect of fragments on the target plate.

NOTE: Several rounds of 90mm AP T33E7 Shot were fired in an attempt to obtain the ballistic limit, at 15° obliquity, of plate 11424C1. This attempt was discontinued, however, after the velocity had been dropped to 1592 fps and complete penetrations were still being achieved. The data gained from this firing substantiated the assumption made during initial firing of this program that velocity levels of 2000 fps or higher would be well above the plate BL.

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BL TEST- 13 September 1954

Round No.	Striking Velocity	Result
1	1759 fps	Complete Penetration
2	1688 "	" "
3	1709 "	" "
4	1592 "	" "

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FIRING DATA

106mm Shell, HEAT, T119E11 (M344)

Test Setup: Target plate No. 11425A; gun to target distance of approximately 156 feet; Striking Velocity of approximately 1600 fps; plate obliquity of 30°; Line Charges with copper liner.

Date & Rd. No.	Distance--Screens to Plate	Distance--Line Charge to Plate	Distance--Line Charge is below line/flight of projectile	Distance--Line Charge Center is off-center from line/flight of projectile	Results
23 August Rd. 1	40"	50"	18"	4"	Line Charge evidently hit projectile; only 2½" * penetration, with jet hole badly deformed. No slug in plate. Jet was deflected several inches away from aiming point and entered plate at an upward angle rather than in a horizontal direction.

* Probe depth

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Firing Data, 1[redacted] (U) Cont

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24 August Rd. 2	20"	30"	18"	4"	Results same as Round 1.
24 August Rd. 3	20"	30"	18"	4"	Line Charge evidently hit projectile: No gouges or jet hole, only explosive blast marks on armor plate face. Zero penetration.
24 August Rd. 4	18"	23"	18"	4"	Line Charge evidently hit projectile: A few shell fragment gouges centered about the aiming point in a vertical pattern, but no jet hole in plate. Zero penetration.
24 August Rd. 5	24"	31"	40"	12"	Line Charge evidently missed projectile: Complete penetration of target plate plus 1½" penetration into the vertical backup armor plate 11 feet behind target plate.
25 August Rd. 6	19"	22"	29"	6"	Line Charge evidently hit projectile: only a few shell case fragment gouges arranged in a vertical pattern centered about the aiming point on the plate. (See APG Photo B2054). No jet hole. Zero penetration.
25 August Rd. 7	22"	23"	42"	9"	Results same as for Round 6.
25 August Rd. 8	27"	25½"	46"	71" NOTE: Line Charge placed 71" to left of line/flight and then tipped so a perpendicular thru its mid-point intersected line/flight.	Line Charge effect on projectile unknown. Damage to plate consisted of a 7" diameter dent approximately ¼" deep on front face, a slight bulge on rear face. No gouges. Apparently round failed to function by fuze action, detonating upon crush-up against the target; no jet formed.

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Firing Da[redacted] (M344) Cont

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25 August Rd. 9	19"	19"	18"	NOTE: Line Charge placed 5/4" to left of line/flight and then tilted so a perpendicular thru its mid-point intersected the line/flight.	Line Charge evidently missed projectile; a complete penetration of the target armor plus a 2" penetration into the vertical back-up plate located 11 feet behind the target plate.
25 August Rd. 10	No Line Charge - Calibration Round				Round failed to function by fuze action at instant of impact, and was detonated during crush-up against the plate. With cone crushed, no jet formed. Effect on plate was identical with Round eight.

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DESCRIPTION OF TRIGGERING SYSTEM

Schematic of BRL(TBL) Triggering System for Initiating Modified Picatinny Arsenal Device

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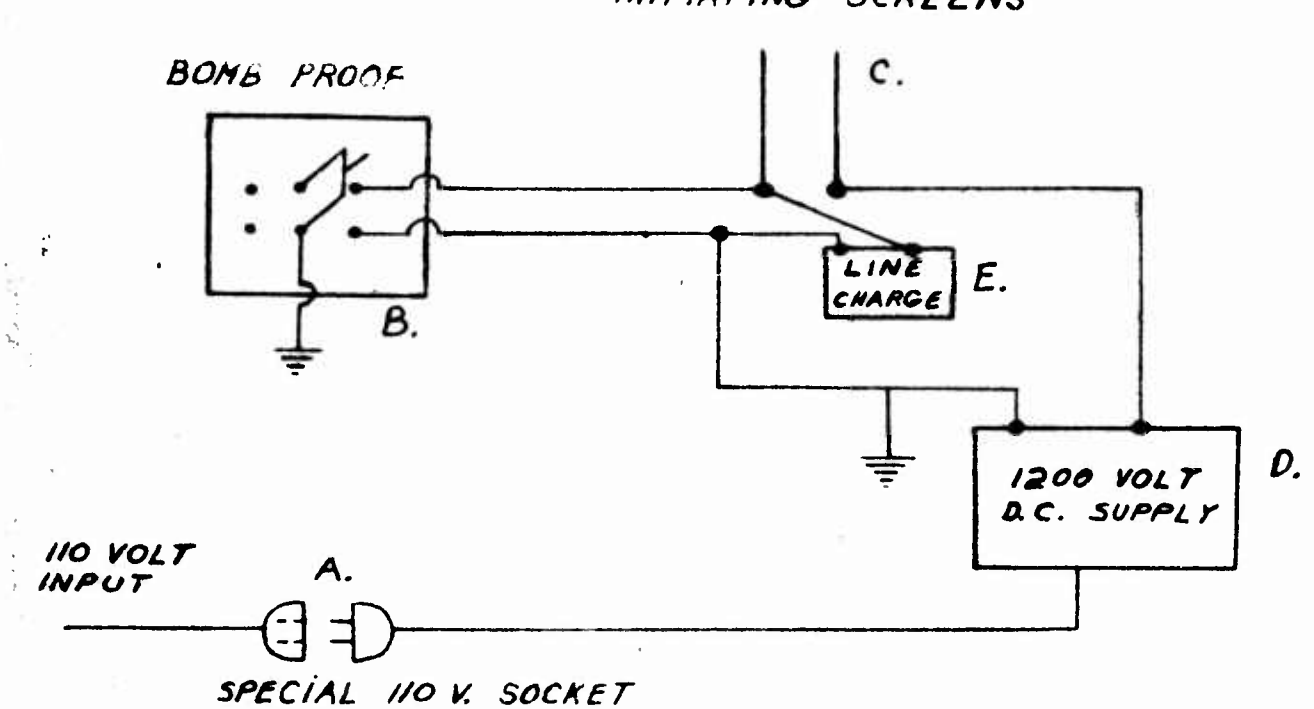
1. Schematic Diagram:



2. Safety Features:

A. A special connecting socket for 110 V input kept by demolition man until he is in shelter.

B. DPDT switch in insulated box, closed and shorted to ground in personnel bombproof (switch opened just prior to firing when all personnel are under cover).

2. Safety Features: continued

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C. Screens checked for infinite resistance to 6000 volts.

D. Power supply shorted to ground prior to firing; unshorted before each firing; shorted after each firing.

E. M36 detonator installed by demolition man in usual manner (leads attached, then M36 inserted into booster through hole in supporting plate for charge).

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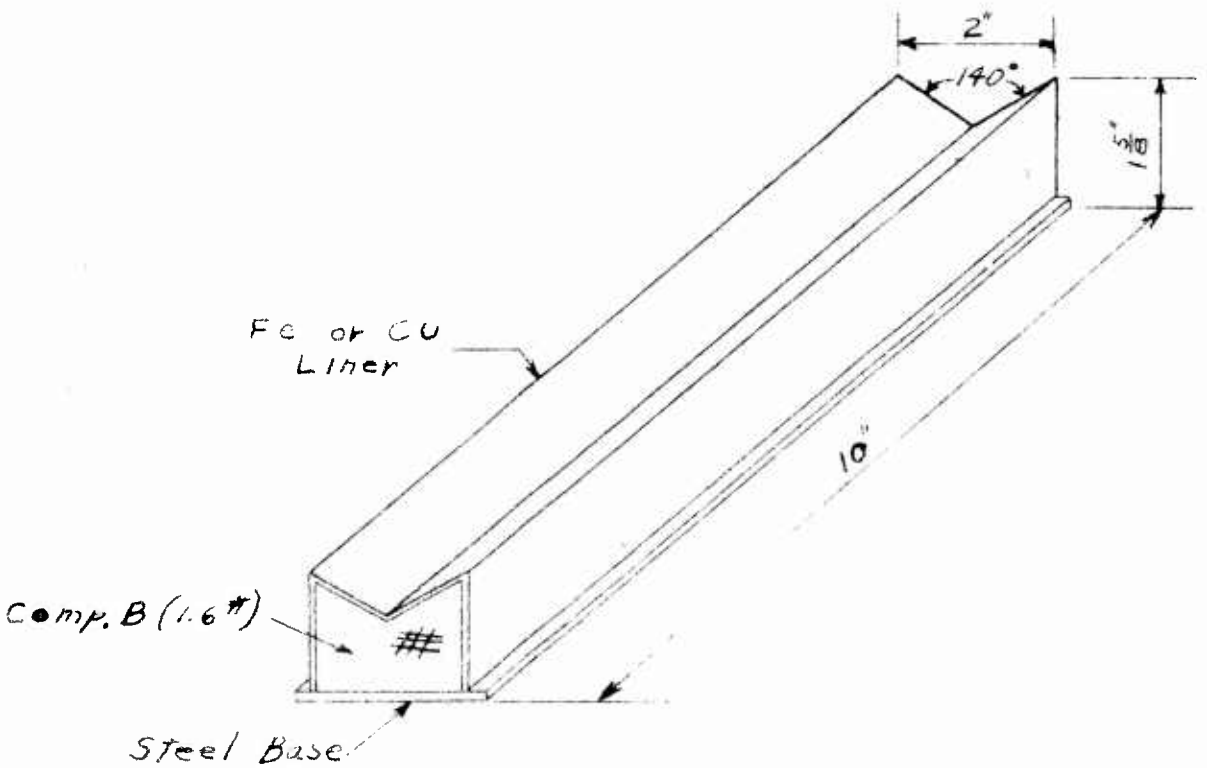
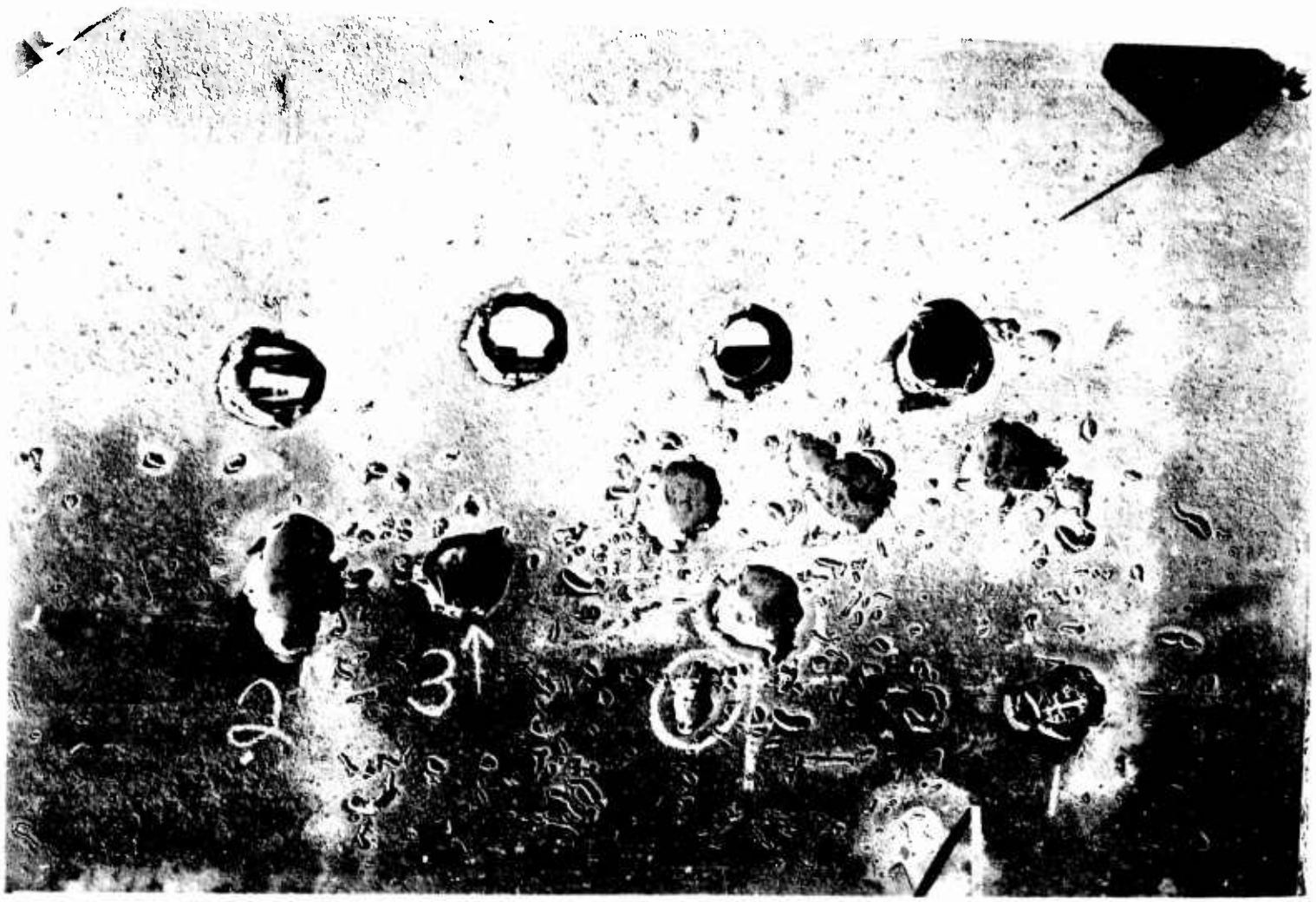
SKETCH OF LINE CHARGE



B2054 CONFIDENTIAL § ABERDEEN PROVING GROUND § 13 September 1954

Project No. TB3-1224B. Testing of Special Picatinny Arsenal Device. Front view of the 4" target plate used during the test of the Picatinny Arsenal Device versus the Shell, 106mm, HEAT, T119E11 (M344). Ten rounds were fired; rounds 3 and 4 are not marked since only negligible scarring resulted from these rounds.



B2055 CONFIDENTIAL § ABERDEEN PROVING GROUND § 13 September 1954

Project No. TB3-1224B. Testing of Special Picatinny Arsenal Device. Front view of the 4" target plate used during the test of the Picatinny Arsenal Device versue the 90mm APT 33E7 Shot. Eleven rounds were fired. Rounds 1 and 2 were fired without use of the Picatinny Device. Round 11, badly broken before striking the plate, is indicated by the circled areas.

B2167 CONFIDENTIAL § ABERDEEN PROVING GROUND § 20 August 1954

Project No. TB3-1224B. Test of Special Picatinny Arsenal Device. Shot, 90mm, AP, T33E7 (Round No. 11), broken in flight by fragments of modified cutting charge.

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APPENDIX D

FIRING DATA - PAD VS 90MM HEP-T

FIRING DATA - PAD VS 90MM HEP

RD. NO. SV(fps)	TRIGGER SCREEN DIST. TO PLATE	RESULT ON PLATE	DIST. PAD BELOW PROJ (Z)	DIST. PAD OFF-SET FROM L OF FLIGHT	DIST. PAD TO PLATE	PAD LINER ANGLE
1 Not Meas.	None Used	Spall	No PAD	-	-	-**
2	None Used	Spall	No PAD	-	-	-**
3	Al.Mesh 30"	No Spall	18"	4"	32"	140°
4 2332	Al.Mesh 30"	No Spall	30"	6"	32"	140°
5 2331	Al.Foil 30"	Spall	60"	10"	32"	140°
6 2336	Al.Foil 30"	Spall	60"	10"	32"	140°
7 2334	Cu.Mesh 30"	Spall	45"	6"	32"	140°
8 2358	Cu.Mesh 30"	Spall	45"	6"	30"	115°
9 2361	Cu.Mesh 30"	Spall	45"	6"	30"	-***
10 2349	Cu.Mesh 43"	Spall	30"	6"	47"	165°
11*	Cu.Mesh 30"	No Spall	18"	6"	32"	115°
12*	Cu.Mesh 30"	No Spall	30"	6"	32"	140°
13*	Cu.Mesh 30"	Spall	45"	6"	32"	140°
14*	Cu.Mesh 30"	No Spall	30"	6"	32"	115°
15*	Cu.Mesh 30.5 ft	No Spall	30"	6"	30.6 ft	140° #
16*	Cu.Mesh 30.5 ft	Spall	45"	6"	30.6 ft	140°
17 2020	Cu.Mesh 30"	Spall	45"	6"	32"	140°

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FIRING DATA - PAD VS 90MM HEP (CONT'D)

SECRET

RD. NO. SV (fps)	TRIGGER SCREEN DIST. TO PLATE	RESULT ON PLATE	DIST. PAD BELOW PROJ (Z)	DIST. PAD OFF-SET FROM L OF FLIGHT	DIST. PAD TO PLATE	PAD LINER ANGLE
18 2320	Cu. Mesh 46"	Spall	45"	6"	34"	140°
19	Cu. Mesh 34 ft.	Spall	45"	6"	34 ft	140° ##

* Velocities not measured. Estimated: 2320-2340 fps.
** Calibration of Ammunition
*** PAD not initiated
# Fastax films taken
Missed screen

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APPENDIX E

FASTAX FILM AND WITNESS PLATE TRIALS

I. PHASE I

A. PURPOSE

Tc obtain fragment velocity and penetration data, using mild steel target witness plates.

SECRET

B. AMMUNITION

Two pads with 140° copper liners. No. 1 was statically detonated with base parallel to ground, mild steel laminate 66 inches overhead. Laminate consisted of two 12 gauge sheets followed by 1/4 inch sheets. No. 2 was detonated with base perpendicular, in longitudinal direction (B), target 66 inches away. Both charges were photographed by Fastax camera to obtain fragment velocity data.

C. PADS 3 and 4

115 degree liners, detonated like No. 2 except that laminate of witness sheets consisted of one 12 gauge mild steel sheet followed by 1/4 inch mild steel sheets. These charges were detonated for fragment distribution data. (See Plots 1,2, and 3). Pad No. 4 was modified to simulate combat conditions as follows: The liner trough or wedge angle was filled with moist soil scraped in the test area. This dirt filler was held in place by masking tape. The charge was detonated against the same setup as was No. 3. A summary of fragment penetration and distribution data is given in Plots 1,2, and 3.

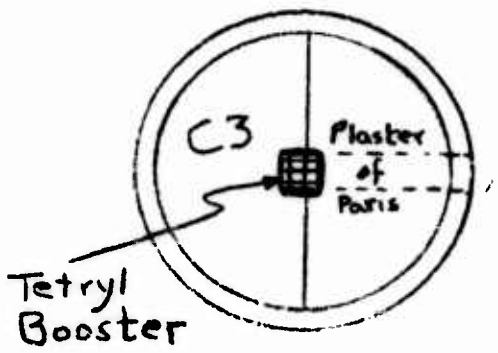
II. PHASE II FRAGMENTATION CALIBRATION

A. PURPOSE

To obtain an indication of PAD fragmentation efficiency and penetration capabilities by comparison with available devices using lesser weights of explosive.

B. PROCEDURE

Two 2 inch I.D. black pipe nipples and four 2 1/2 inch I.D. galvanized pipe nipples were capped at one end. Each was then filled lengthwise with an inert mixture (Plaster of Paris) for one half of the nipple diameter, looking in section like this:



The plaster filling was then drilled thru, at the center of the nipple length, for a tetryl booster pellet. The remaining semi-circular section was then filled with explosive C3. A tabulation of the pipe charge characteristics follows:

C. PIPE CHARGE DATA

SECRET

Pipe ID	2 inches	2 1/2 inches
Pipe OD	2 3/16 inches	2 13/16 inches
Pipe Length	6 inches	10 inches
Pipe Type	Black	Galvanized
Wt Charge	.53 ±.03 lb C3	1.3 lbs C3
Wt Pipe, two Steel Caps (at ends) & Inert Load	4.75 lbs	10.2 lbs
Wt of Single Cap	1.15 lbs	2.15 lbs
Wt as fired w/one cap	5.3 ±.10 lbs	9.3 ±.10 lbs

D. RESULTS

1. When the 2 inch pipe nipple was detonated from a position with its axis parallel to the ground, the fragment pattern obtained was apparently too limited to be comparable to a PAD. The next charge used was the larger diameter, longer, 2 1/2 inch I.D. nipple. This charge, effectively a miniature bangalore torpedo, was detonated with the axis perpendicular to the ground. The large angle of fragment distribution is apparent from APG photographs B5971-73. This pattern might be considered inherent in the shape of the charge casing. Also noteworthy are: reduction in numbers of fragments for the thick steel pipe casings and greater proportion of penetrating fragments in later witness sheet (No.3).

2. A tabulation of fragmentation data for the first of each type of pipe nipple and the four PADS detonated in the last phase of this program is given below. Two additional pipe nipples of each type (2 inch I.D. and 2 1/2 inch I.D.) were detonated with axis vertical. Fragmentation data, density, and numbers of indentations in each mild steel witness sheet are summarized in Plots 1, 2, and 3 which follow.

MILD STEEL WITNESS PLATE FIRINGS

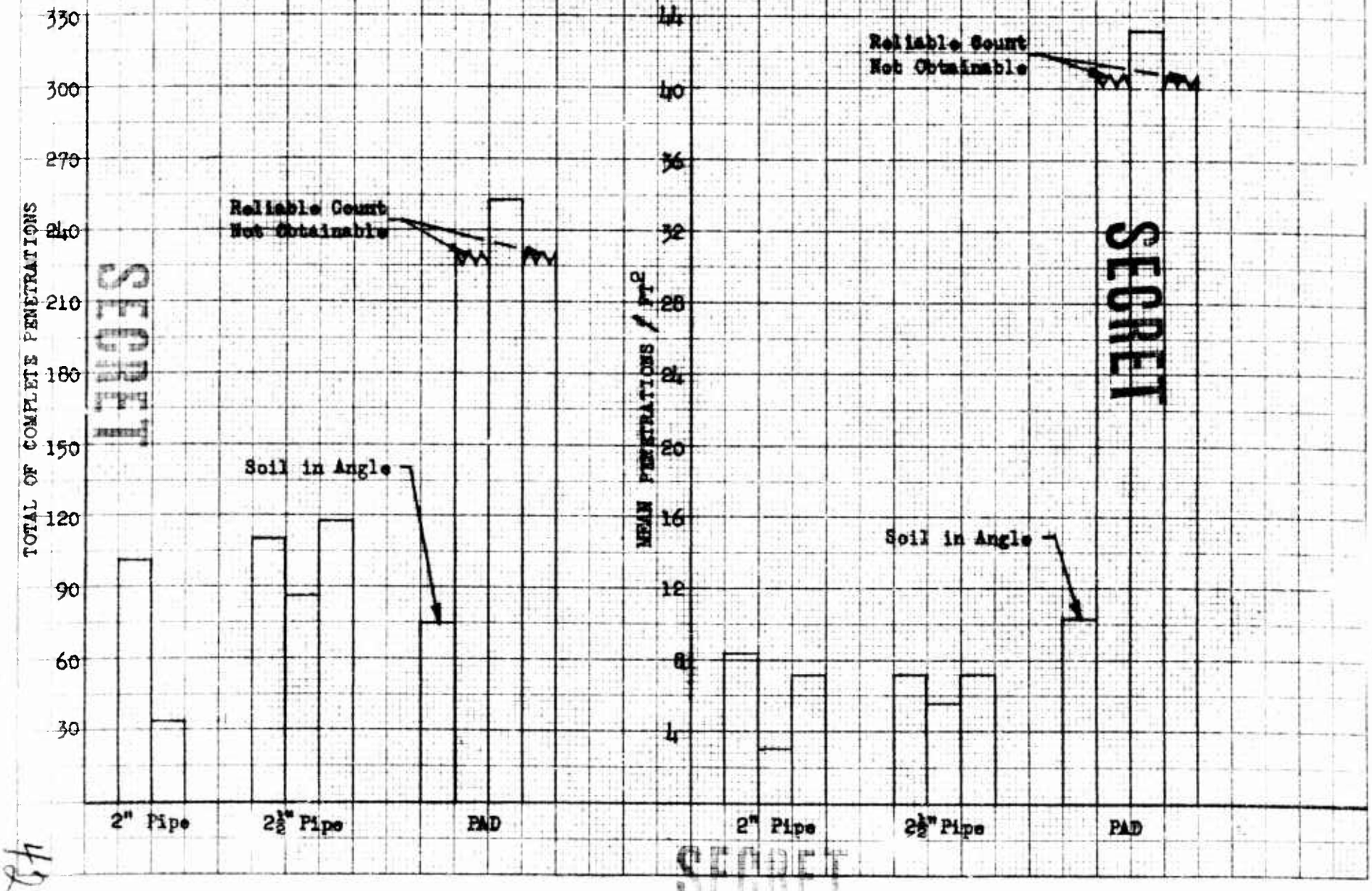
SECRET

CHARGE	WITNESS PLATES	SPREAD(") OF INDENTATIONS VERT.	SPREAD(") OF INDENTATIONS HOR.	SPREAD(") OF PENETRATIONS VERT.	SPREAD(") OF PENETRATIONS HOR.	TOTAL NO. OF INDENTATIONS	TOTAL NO. OF PENETRATIONS	DENSITY OF INDENTATIONS	DENSITY OF PENETRATIONS
PAD #1	10 ga	10	51	10-14	51	Large areas of tiny & large		Too high to count	
140° Liner	12 ga	10	51	6	32	117	23	.23/ft²	.12/ft²
	1/4"	8	42	6	23	65	6	.20	.04
	1/4"	8	35	-	23	34	4	.12	-
PAD #2						Very			
140° Liner	12 ga	21	40	21	40	Large	25.3	-	.30
	12 ga	21	40	21	40	"	60	-	.07
	1/4"	21	40	16	29	164	5	.20	.01
	1/4"	30	36	-	-	13	1	.02	-
				STEEL PIPE NIPPLES					
Pipe #1	12 ga	36 ≠	14	36 ≠	14	-	25	-	7.12
2" ID	12 ga	36 ≠	14	36 ≠	14	51	10	.10	.02
Axis at	1/4"	36 ≠	14	-	-	16	-	.03	-
0° elev.									
Pipe #2			Over		Over				
2 1/2" ID	12 ga	24	8 ft	24	8 ft	Large	118	Large	7.08
Axis at	1/4"	24	"	-	83"		5	9.34	
90° elev.	1/4"	24	"	-	-		1	3.06	
						Very			
PAD #3	12 ga		48	15	55	Large		-	-
115° Liner	1/4"	27	48	12	55	"	16	21.3	1.7
	1/4"	15	41	-	-	41	-	9.6	-
	1/4"	12	41	-	-	19	-	5.5	-
							Approx.		
PAD #4	12 ga	30	35	30	35	Large	75	Large	10.26
115° Liner*	1/4"	30	35	0	20	2.08	2	28.5	-
	1/4"	24	32	-	-	13	-	2.4	-
	1/4"	Center of Plate				2	-	-	-

* Sandy loam loosely held in wedge by masking tape.

SECRET

PLOT NO. 1 - FRAGMENT DISTRIBUTION IN FIRST SHEET (12 GA., MILD STEEL)
OF WITNESS PLATE LAMINATE



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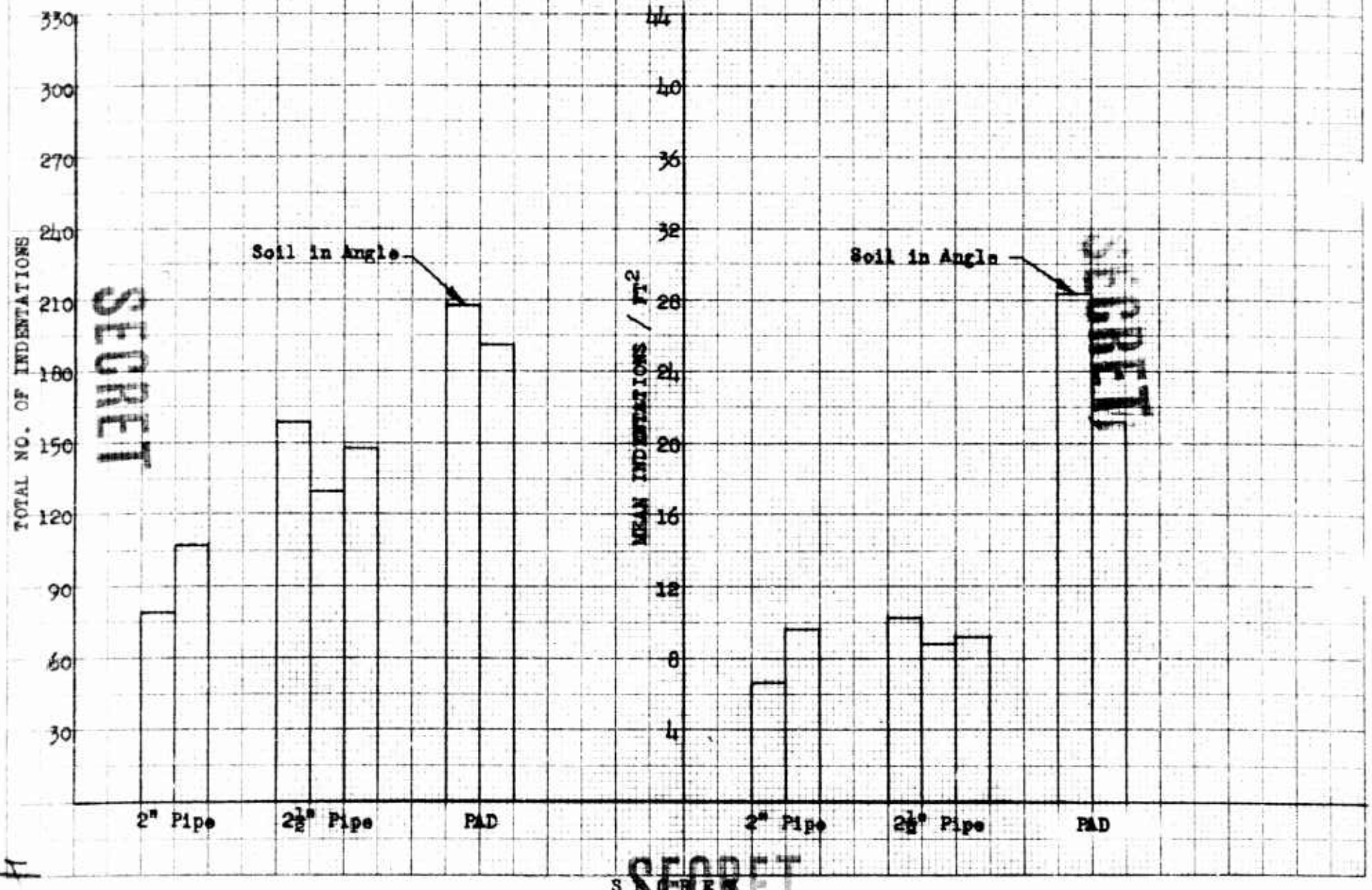
PLOT NO. 2 - FRAGMENT DISTRIBUTION IN SECOND SHEET ($\frac{1}{4}$", MILD STEEL)

OF WITNESS PLATE LAMINATE



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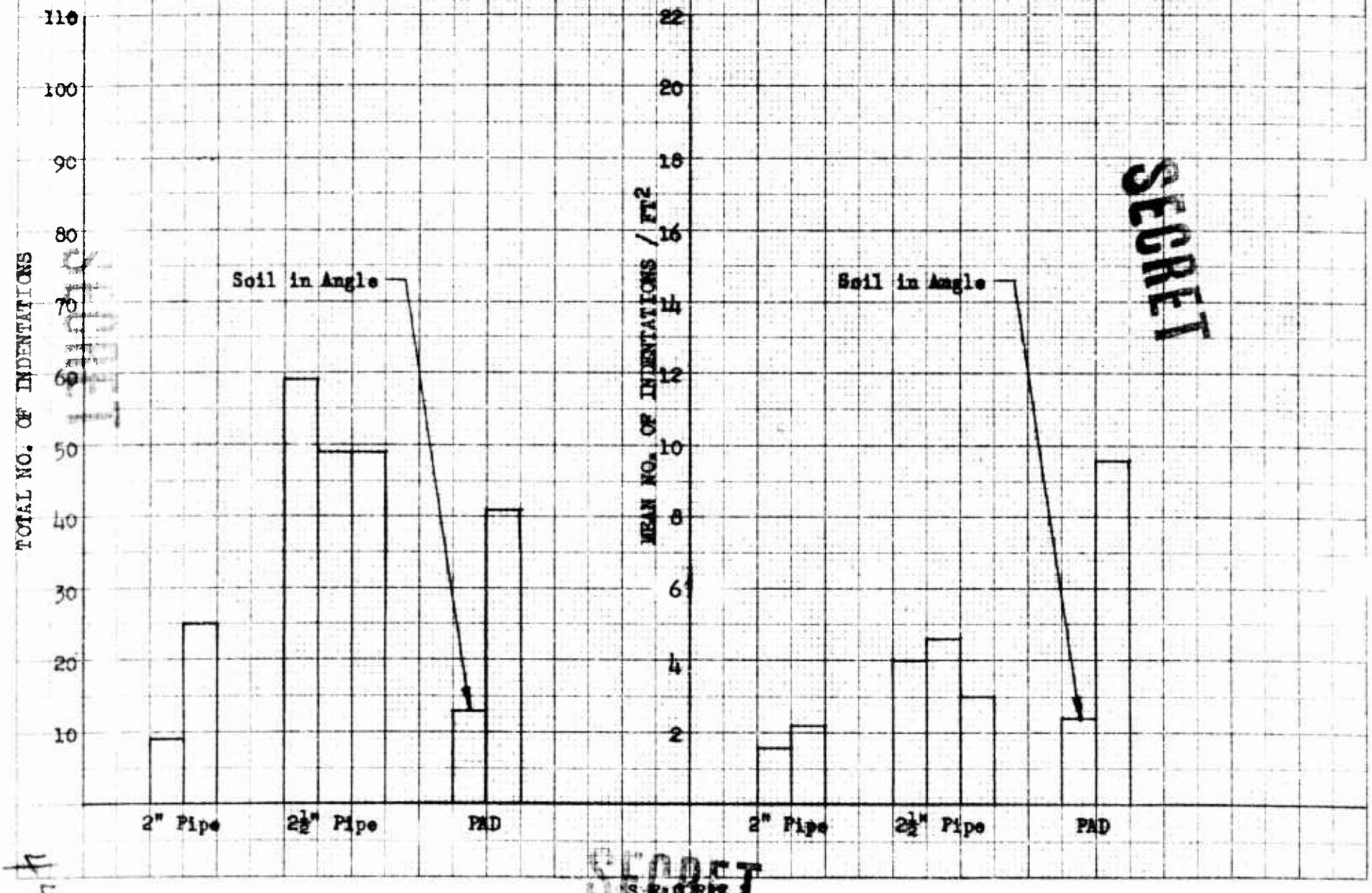
PLOT NO. 3 - FRAGMENT DISTRIBUTION IN THIRD SHEET ($\frac{1}{4}$", MILD STEEL)

OF WITNESS PLATE LAMINATE



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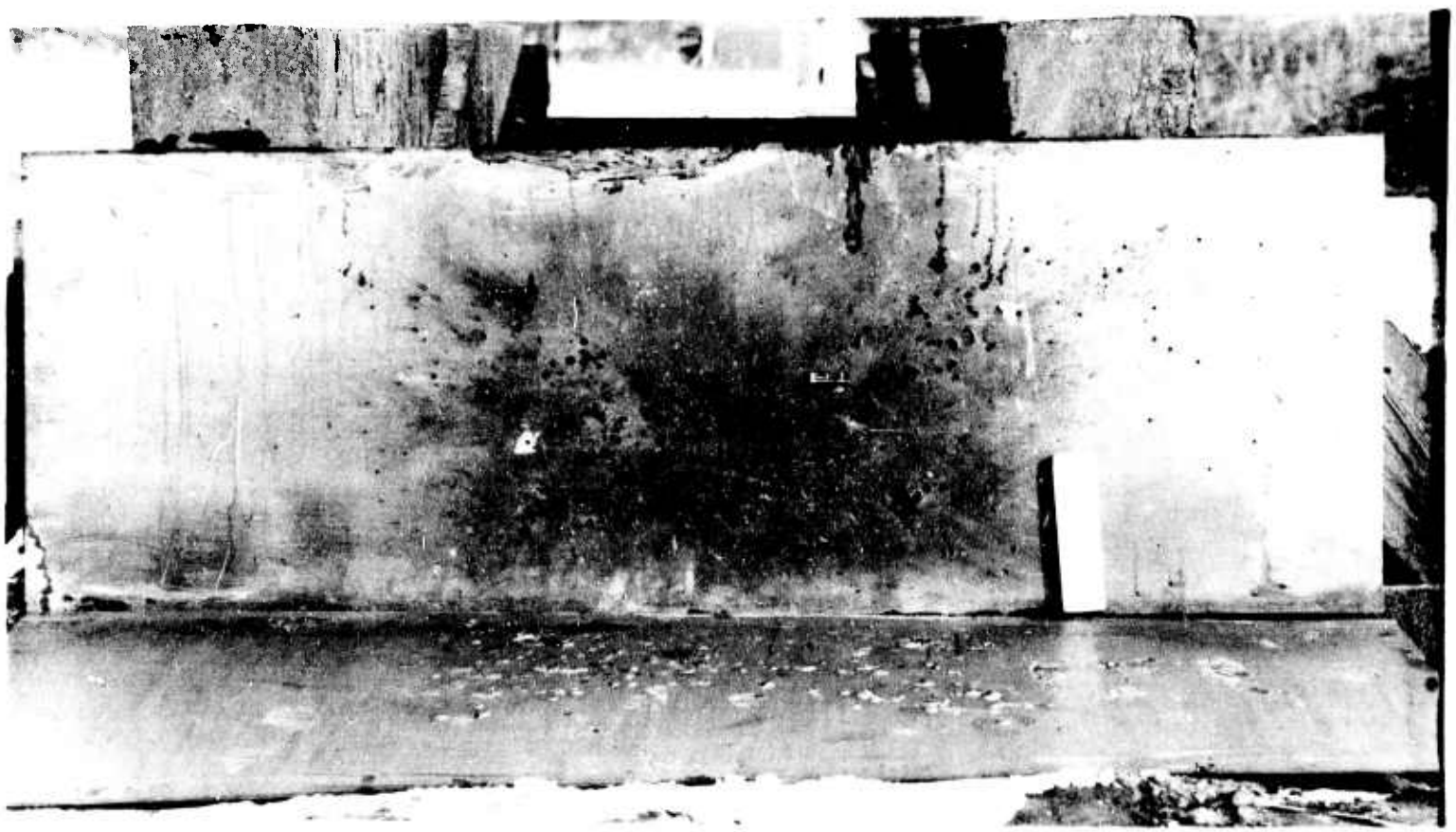
APPENDIX F

APG PHOTOGRAPHS NOS. B5968 THRU B5973

SECRET



B5968 SECRET ABERDEEN PROVING GROUND 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Pad No. 2. Fragment damage 66" from charge in first sheet (12 ga.) of witness plate laminate.

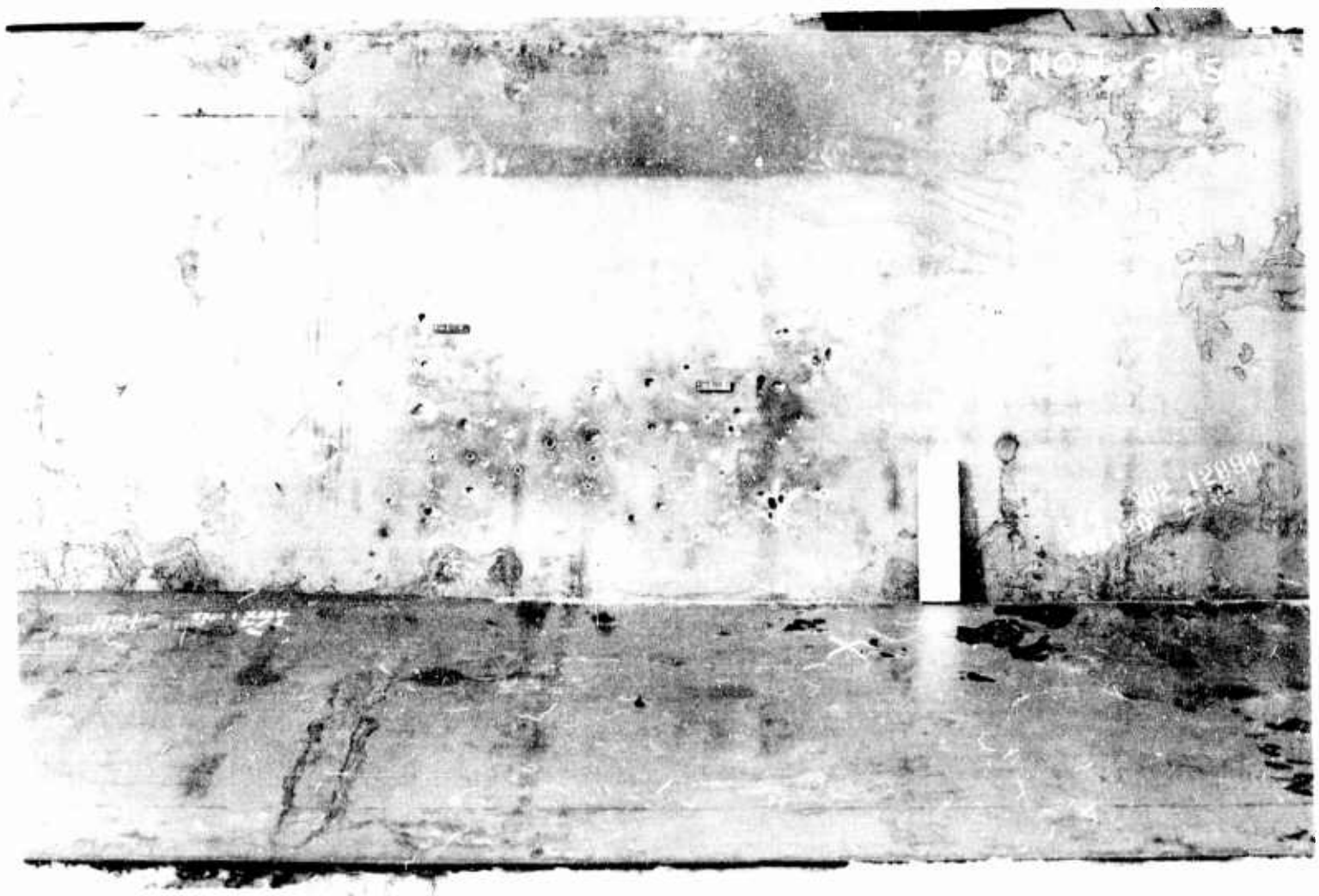
SECRET

B5969 SECRET ABERDEEN PROVING GROUND 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Pad No. 2. Fragment damage 66" from charge in second sheet (12 ga.) of witness plate laminate.

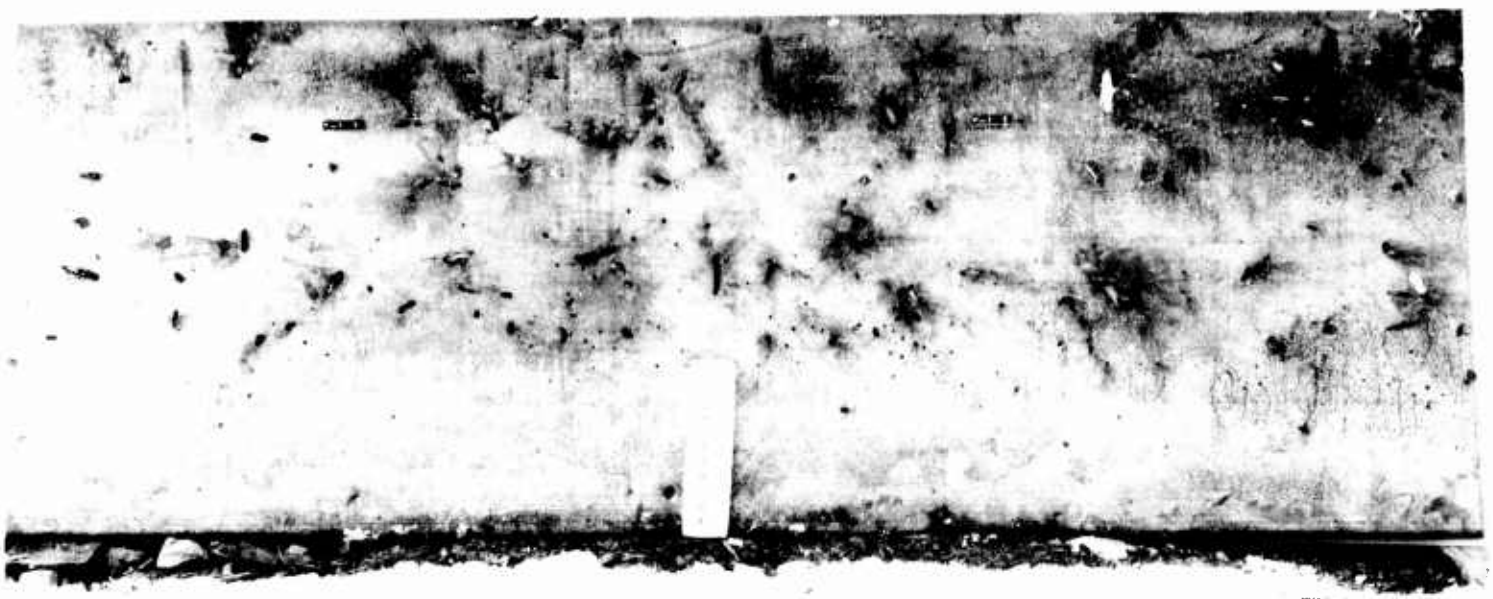
SECRET



B5970 SECRET ABERDEEN PROVING GROUND 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Pad No. 2. Fragment damage 66" from charge in third sheet (1/4") of witness plate laminate.

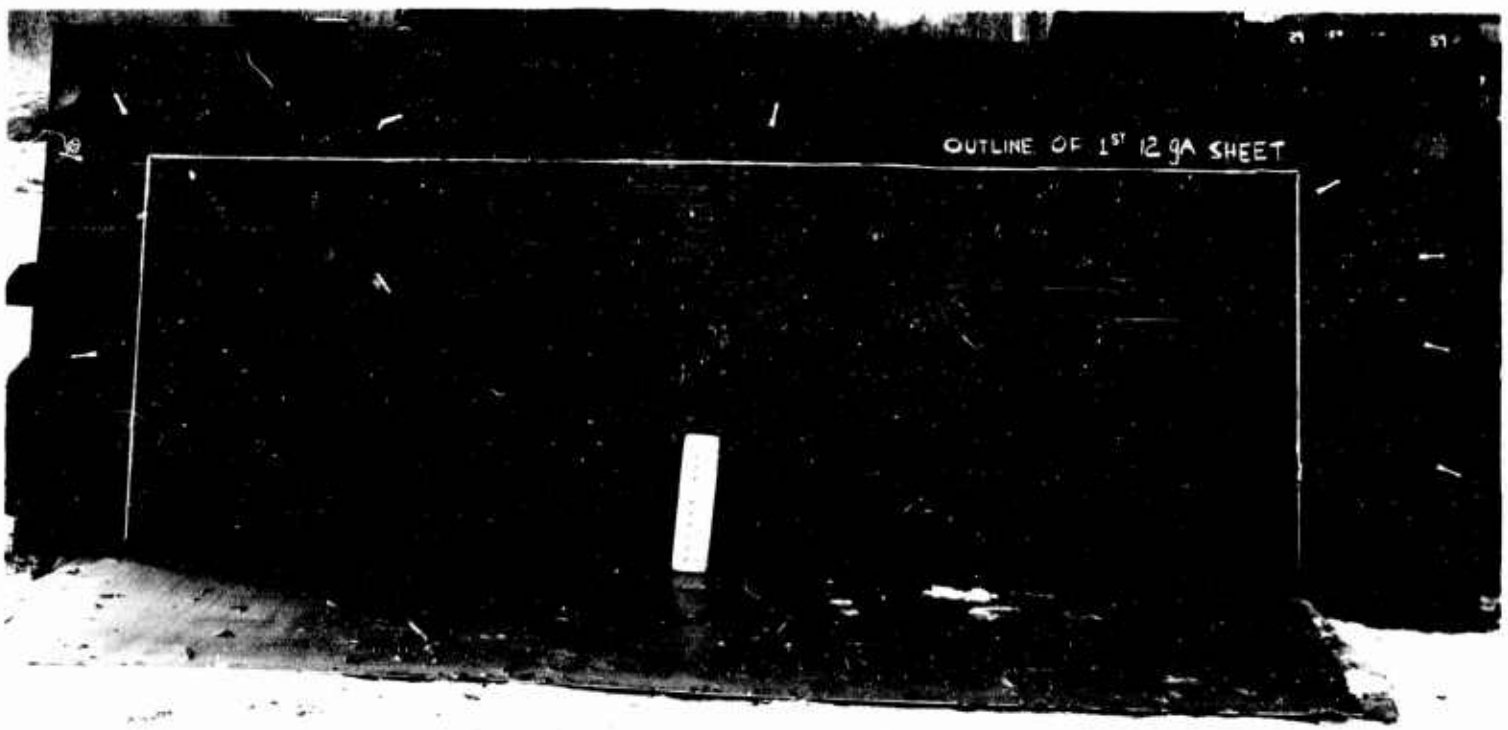


B5971 SECRET § ABERDEEN PROVING GROUND § 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Special Device No. 2. Fragment damage 66" from charge in first sheet (12 ga.) of witness plate laminate.

SECRET

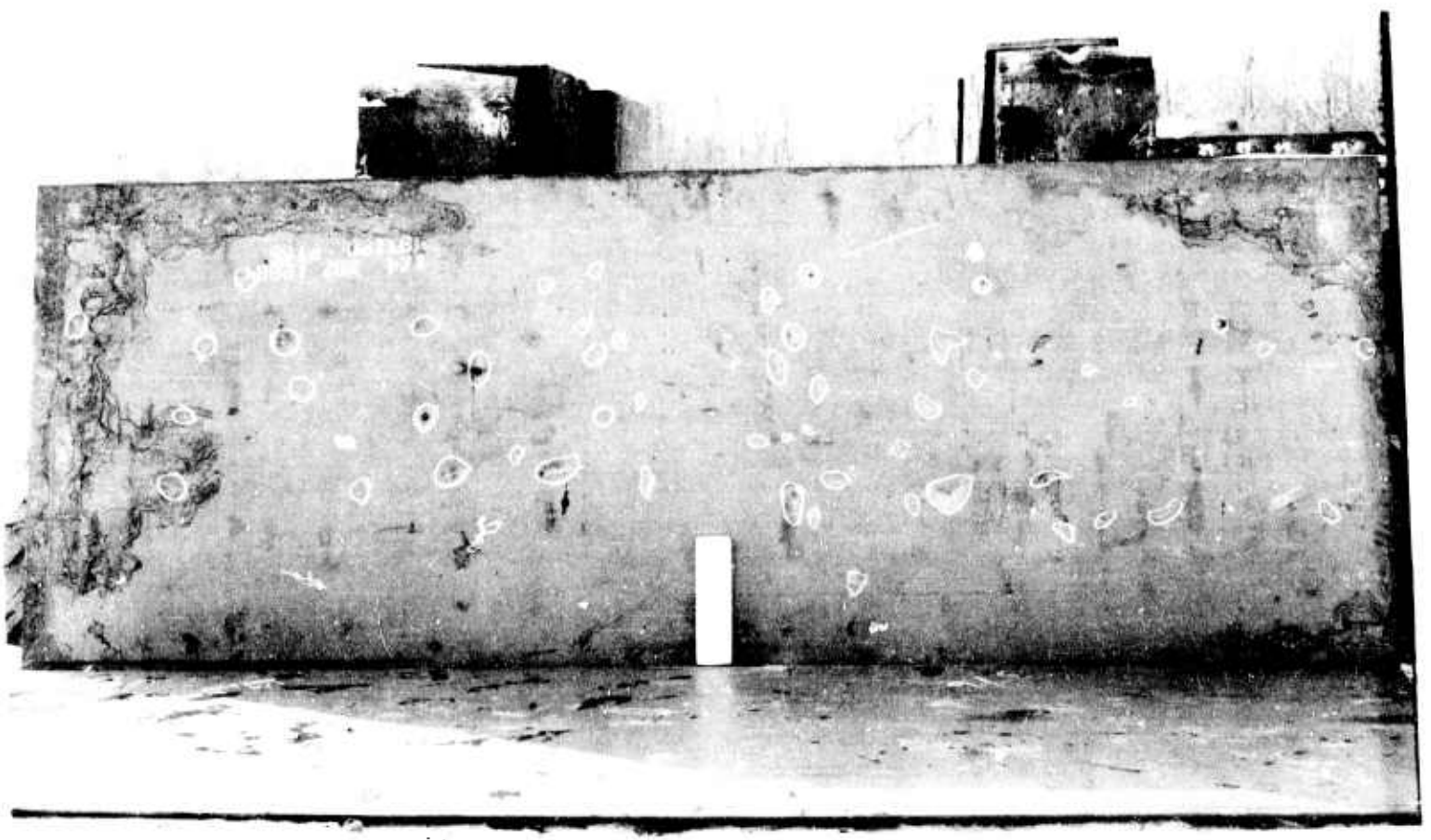


B5972 SECRET ABERDEEN PROVING GROUND 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Special Device No. 2. Fragment damage 66" from charge in second sheet (1/4") of witness plate laminate.

SECRET



B5973 SECRET ABERDEEN PROVING GROUND 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Special Device No. 2. Fragment damage 66" from charge in third sheet (1/4") of witness plate laminate.

DISTRIBUTION FOR ELEVENTH REPORT ON PROJECT TB3-1224B (CONT'D)

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I. INTRODUCTION:

A. DISCUSSION

1. On 28 July 1953, a conference on Defense Against Shaped Charges was held at the Ballistic Research Laboratories, APG. This conference resulted in the formation of the Ordnance Corps Committee on Defense Against Shaped Charges.* At this same conference, a unique method of defense against shaped charge missiles, evolved by Picatinny Arsenal personnel, was described. In this method, a lined explosive charge,**triggered by an incoming projectile, produces a sheet of fragments in a plane roughly normal to the trajectory of the missile. These fragments strike the HEAT shell body and so damage it that the shell loses its penetration capabilities. The application of this device then envisioned was the setting of a series of such charges on the stowage boxes, fenders and turret periphery of a tank, as necessary.

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2. The lined explosive charge demonstrated initially was referred to as a "linear cutting charge," after the British terminology. It was described more fully at the first meeting of the above-mentioned Committee on 25 September 1953.

3. At the meeting in September 1953, the charge model was described by Picatinny Arsenal as approximately eight inches long, carrying a little over a pound of explosive, with a T18 detonator and annular booster near each end, making for two-point initiation. In the first tests by Picatinny Arsenal, seven 3.5 inch HEAT M28A2 rockets were fired at armor plate, first striking a pair of aluminum foil electric-detonator triggering screens in front of the plate. These screens, on short-circuiting, permitted the detonator system to initiate the charges. No 3.5 inch rocket round penetrated more than three-fourths of an inch of the armor against which it was fired.

4. The suggestion was made by the D&PS representative at this meeting that such a device was potentially even more valuable against other missiles than HEAT. This was predicated on two possibilities:

a. Effective breaking up or cracking of a large caliber armor-piercing shot might be achieved by the impact of liner fragments on the projectile body. This aspect was investigated in the tests to be described.

b. The impact of a liner fragment of sufficient momentum might deflect or upset the target missile by an amount sufficient to prevent complete penetration of the target armor. An elementary study of this aspect indicated that upsetting a large caliber projectile of the AP or AP HE type by fifteen degrees (a conservative guess of the amount necessary to degrade the penetration capability of typical AP projectiles fired against oblique armor) requires an inordinately large fragment momentum. A limiting condition is the distance the missile must travel, before it strikes the target armor, after being hit by a liner fragment.

5. a. A basic limitation of the method of defense by this explosive device is the necessity for a reliable and accurate sensing and triggering system. One

* Ref.: Letter from ORDTB, File No. 334/924, APG 337/900
** See sketch in Appendix B

reason given for the relatively slow development of the charge is that without an automatic, quick-acting, sensing and initiating system, it is relatively useless for its intended purpose.

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b. Considerable progress has been made, however, in the direction of developing a sensing and triggering system, under project DASH DOT, Ordnance Project No. TA3-5204. Under technical supervision of the Picatinny Arsenal, the United Shoe Machinery Corporation has developed an electronic mechanism system for the purpose described above.

c. The following is a description of the system provided by the contractor in a progress report.

A method using C.W.X. band radar has been tentatively adopted for the detection of attacking missiles. Missile velocity is determined by the doppler frequency produced by the impact of the transmitted energy on the approaching missile. The range of missile velocities involved requires the production of a time delay which increases as the missile velocity decreases, in order that all missiles may be in the same vertical plane at the instant of detonation of the linear charge which is used to defeat the missile. The delay required for all missiles between 200 and 3000 feet-per-second velocities has been worked out, theoretically resulting in all missiles being in the same vertical plane $\pm$ 1.43 inches over a vertical distance of 5 feet. Various methods of developing the required delay have been explored and a breadboard model of a simple and reliable method has been constructed. The delay available has been extended to 3800 microseconds maximum, to include low velocity missiles arriving at extreme angles of obliquity. The radial velocity of a 200 feet per second missile may be only 67 feet per second, producing a doppler frequency of some 1360 cycles per second. A "missile simulator" in which Styrofoam cylinders are propelled along a plexiglass tube has been constructed to enable preliminary tests to be run in the laboratory. Missile velocities in excess of 350 feet per second have been obtained in the "simulator" and velocities up to 500 feet per second should be possible with increased air pressure.

d. A description of the instrumentation used is provided in the January 1955 progress report by the same agency.

e. A test with the breadboard model sensing dynamically-fired artillery missiles was described at the meeting of the Ordnance Corps Committee on Defense Against Shaped Charges on 1 Nov 1955. The test results were generally satisfactory.

f. A second limitation of the device in its present form is that connected with exposed mounting on a vehicle. With the apex of the liner in normal position, so that fragments can be projected upward, the device may accumulate mud, dust and snow in the exposed cavity. A brief, inconclusive test of the PAD was conducted in conjunction with the calibration and high speed movie firings to investigate this limitation. Some reduction in fragment energy was noted with one charge.

6. Countermeasures that might be employed against a successful application of a radar-controlled PAD* system to a vehicle would depend to a large extent on the performance of the sensing system and the location of the PAD.

a. If the charges were mounted close to the tank surfaces, and aimed vertically, it might be feasible for the enemy to use and attacking HEAT missile which attempted to detonate before the PAD did. A large diameter (6 in. and up), long-ogived, HEAT round, performing better at a long standoff than conventional ones, might be adequate for penetrating the tank defended by PADs, in the arrangement described.

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b. A more complex round might incorporate the above features and a proximity fuse as well.

c. The above speculative anti-PAD missile designs add additional support to the Proving Ground's interest in the design and development of PAD type devices for other applications (i.e. anti-AP, anti-HE shell, anti-personnel, anti-mine).

d. Finally, while beyond the province of this report, it is not overlooked that PAD type devices may prove feasible as protective measures in some US Air Force and US Navy materiel. Air-to-air defense against chemical energy missiles is an application worthy of serious consideration and extensive development.

B. REFERENCES

1. Ltr, ORDTB 334/924, APG 337/900. Subject: Ordnance Corps Committee on Defense Against Shaped Charge Program.

2. Memorandum from Director BRL to Director, D&PS, 2 August 1954.

3. Memorandum from Director BRL to Director, D&PS, 3 November 1954.

4. Monthly Progress Reports on Ordnance. Project TA3-5204 (DASH DOT) by Research Division, United Shoe Machinery Corp.

5. Minutes of the Ordnance Corps Committee on Defense Against Shaped Charge Weapons, November 1955.

* The term PAD (Picatinny Arsenal Device) was proposed by the D&PS and accepted by the Picatinny Arsenal representative at a Committee meeting.

II. DESCRIPTION OF MATERIEL

A. Some modification of the first demonstration model of the Picatinny Arsenal device was effected by the Terminal Ballistics Laboratory, BRL. A single point initiator (M36) was substituted for the twin initiators hitherto used.

SECRET

1. A flash radiograph of the fragment pattern of such a charge is provided in Vol. I, No. 2 of the Ordnance Corps Shaped Charge Journal, Oct. 54, (Pages 276-277).

2. This radiograph shows the divergence and critical curvature of a single-point initiated sheet jet. A 3-point-initiated charge with an essentially straight front, had interacting jets where the main fronts met at the liner. This charge had a ninety degree wedge angle with a 1/16 inch copper liner. For the dynamic firing tests described herein, the TBL-BRL versions of the PAD were used. A sketch of a typical PAD is provided in Appendix B. The devices used were ten inches long and loaded with 1.67 lbs. of C3. In section the steel or copper liner resembles the letter M. The interior angle was usually large, ranging from 115 to 165 degrees for different liner designs and materials.

B. Target armor for the dynamically-fired projectiles was rolled homogeneous armor of varying thicknesses and obliquities. Thickness and obliquity were combined so that the projectile could defeat the armor unless degraded by the PAD fragments. Major items used are listed below:

PROJECTILE	WEAPON	ARMOR	OBLIQUITY
90mm AP, T33E7	Gun, M3	4 inches R.H.	15°
90mm HEP-T, T142E3	Gun, T119	2 inches R.H.	55°
106mm HEAT, T119E11	Rifle, M70	4 inches R.H.	30°

III. DETAILS OF TEST

A. PROCEDURE

1. For the major test phases, i.e., defeat of dynamically fired missiles, the target armor was placed in plate butts to provide obliquity in the vertical plane. The charges (PADS) and triggering screens were then positioned on the ground, usually a few feet from the armor. These distances were changed as test requirements dictated. The vertical and the horizontal distances between the charge and the trajectory of the attacking projectile were varied for different projectiles.

2. When the projectile was fired at the target armor, it passed through and short-circuited a pair of closely spaced aluminum foil or wire mesh screens. This permitted initiation of an M36 electric detonator which in turn initiated the PAD. A successful PAD was one which prevented complete penetration of the armor by the attacking (target) projectile.

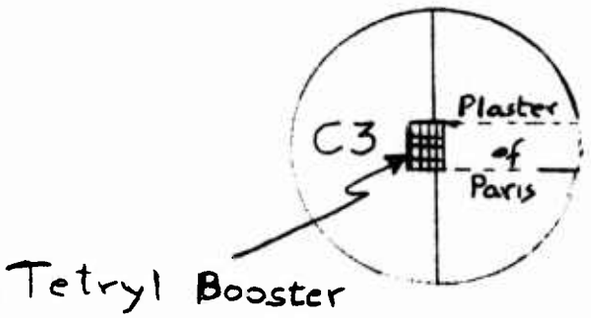
3. When test results dictated, fastax films were taken to obtain data on the behavior of the PAD fragments and on the target projectile.

4. To obtain data on PAD fragment velocity and penetration characteristics, special detonation tests were conducted in a final test phase. PADs were detonated so that fastax films of fragments striking mild steel plate could be made. The time interval between the detonation and the flash caused by a fragment striking the target was computed from the film. Since the charge to plate distance was known, the velocity of the fastest liner fragments was determined.

SECRET

5. The PAD liner fragments were checked for depth of penetration into mild steel, both with and without a filling of mud in the liner wedge. It appeared that such penetration was limited for the weight of explosive used. Accordingly, a crude comparative fragmentation test was devised.

a. Locally available steel pipe nipples, 2 inches ID by 6 inches long, and 2 1/2 inches ID by 10 inches long, were half-filled, axially, with plaster of paris. A hole was drilled in the nipple wall at mid-length, thru the inert filler, to house a tetryl pellet. Explosive C3 was then pressed into the remaining semi-circular segment of the pipe, for its full length. In section, the pipe looked like this:



B. RESULTS

1. Detailed firing data and results for the PAD vs 90mm AP T33E7 shot and vs the 106mm HEAT T119E11 are contained in F.R. No. Ar-20352, a copy of which forms Appendix C.

a. With steel-lined PADs eighteen inches below the trajectory, 90mm AP T33E7 projectiles were defeated four times in four, at projectile velocities of the order of 2050 fps. The defeated projectiles were cracked or broken by liner fragments as shown by one smear type photograph, APG B2167, in Appendix C; when the velocity of the attacking T33E7 projectile was increased to 2500 fps, the projectile defeated the target armor in the limited firings conducted. The exact interaction between liner fragments and successful projectile is not known. A change in liner design or orientation may be adequate for defeating the higher velocity projectile. (For attack at 15° obliquity by 90mm AP T33E7, the ballistic limit velocity of a 4-inch rolled homogeneous armor plate like the target plate is usually of the order of 1700 fps).

b. With copper-lined charges at the same distance (18 inches below and 4 inches off center of the trajectory), several recoilless rifle rounds, 106mm HEAT, T119E11, were defeated. At 29 inches below and six inches off center, and at forty-two inches below and nine inches off center, the PAD was successful. One round was fired for each condition described.

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c. Several of the other rounds fired in this 106mm T119E11 series were of dubious quality, however. This was evidenced by a fuze failure on a final T119E11 fired as a check. Without a PAD in position to attack it, this last round broke up on the face of the target armor plate without proper functioning.

2. Detailed firing data and results for the target 90mm HEP-T T142E3 projectiles, fired at velocities of the order of 2320 fps, are contained in Appendix D. Copper lined charges with included angles of 115°, 140° and 165° were used. A summary of results follows:

PAD LINER ANGLE	VERTICAL STANDOFF (PAD below Trajectory)	RESULTS
115°	1 at 18 inches	Projectile defeated
	1 at 30 inches	Projectile defeated
	1 at 45 inches	Projectile not defeated
140°	1 at 18 inches	Projectile defeated
	3 at 30 inches	Projectile defeated
	6 at 45 inches	Projectile not defeated
	2 at 60 inches	Projectile not defeated
165°	1 at 30 inches	Projectile not defeated

3. It appears then that vertical distances greater than thirty inches are too much for the PAD, as tested, against 90mm HEP-T, T142E3.

4. When it seemed that fragment energy fall-off or some similar factor was critical over a short distance (i.e., from 30 to 45"), fastax films to obtain liner fragment velocity data were taken. Inspection of films indicated that a few of the fastest liner fragments were of approximately uniform velocity (11,000 fps) over a six foot distance. Velocity data for most liner fragments was not obtainable by standard high speed photography methods.

5. Static detonation of the charge for fragment penetration data indicated fairly limited spread and penetration. (See Appendix E and Photos). Comparable penetrations and wider spread were obtained using locally available 2 1/2 inch galvanized steel pipe nipple and lesser explosive charge weights.

6. When the wedge or cavity of one charge was filled with moist soil, a fall-off in fragment penetration was observed.

C. OBSERVATIONS

1. a. The defeat of attacking chemical energy ammunition (HEAT, HEP-T) resulted from high order detonation of the explosive charge. This, in turn, resulted from copper-liner fragment penetration of the shell body.

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b. A high order detonation of an incoming missile may be undesirable* for the vehicle being defended. Attempts to defeat chemical energy ammunition by lower energy particles may be desirable from this standpoint as well as from the standpoint of reducing the amount of explosive filler in the defending charge.

2. The maximum vertical distance required between incoming missile and liner varied with each type of missile. For defeating kinetic energy rounds, a shorter distance may be required. If this is so, a determination of the major missile targets should be made. This re-evaluation of the mission of PAD type devices is necessary because of the possibility of specially designed ammunition of the HEAT type which might frustrate such a device (See IA-Discussion).

D. OBSERVERS

In addition to D&PS and BRL personnel directly connected with these firings, the following were present for some phases of the HEP-T firings:

Mr. Paul Willner - Picatinny Arsenal

Mr. J. L. Minto - United Shoe Machinery Corp.

IV. CONCLUSIONS

A. The PAD (Linear Cutting Charge) as tested offers considerable promise for protection of armored targets against chemical energy ammunition of the HEAT and HEP type.

B. The device also offers considerable, if not superior promise for use against high explosive shell, armor piercing projectiles and similar artillery ammunition.

C. As tested, the performance against 90MM AP ammunition fell below that against HEP-T and HEAT.

D. The tactical performance of such a device may be limited by environmental conditions such as terrain, snow, dust, etc.

E. The test data does not permit selection of an optimum liner material or configuration until tactical objectives and limits of performance have been established.

* Large caliber HE filled shell may cause serious blast damage on the tank exterior. Fragments resulting from a high order detonation would also be a serious damage threat. A low-order detonation, or mere shell break-up, is therefore preferable.

V. RECOMMENDATIONS

SECRET

A. The development of explosive and liner combinations should be extended to provide a determination of the most effective system.

B. The application to defeat foreign HEAT and kinetic-energy artillery ammunition should be stressed in future development.

C. Increased versatility of the device should be a major objective in future design, with some attention to anti-personnel utilization.

D. Tests to determine operational suitability on a moving vehicle should be initiated. Performance under varying weather and terrain conditions should be investigated.

E. Specific military characteristics should be made the basis of future design. These characteristics should take into consideration the limitations and potential versatility of the charges tested as described in this report as well as such obvious considerations as safety of tank crews and tank-accompanying infantry.

Arthur Pillersdorf
ARTHUR PILLERSDORF
Eng. Ordnance

Benjamin S. Goodwin
BENJAMIN S. GOODWIN
Assistant Director for
Engineering Testing
Development & Proof Services

Herbert L. Rosenberg
HERBERT L. ROSENBERG
Chief, Terminal Ballistics
Division

SECRET

APPENDICES

APPENDIX A - Correspondence

APPENDIX B - Sketch of PAD

APPENDIX C - Firing Record Ar-20352

APPENDIX D - Firing Data and Results - PAD vs 90mm HE-P

APPENDIX E - Witness Plate and Fragmentation Data

APPENDIX F - APG Photographs Nos. B5968-B5973 inclusive.

1956

APPENDIX A

CORRESPONDENCE

1. Interoffice Memo from Director, BRL to Director, D&PS dated 2 August 1954 with 1st Indorsement dated 19 October 1954
2. Interoffice Memo from Director, BRL to Director, D&PS dated 3 November 1954
3. Letter, File APG (S) 471/31, 00 4S-/8892
4. Teletype ORDBB-TR1 TT8696 22706 7 1954

Request for Firing of 90mm Kinetic Energy Rounds and 105mm Recoilless HEAT Rounds

1st Ind Mr APillersdorf/hlc/23229

SECRET

Director, Development & Proof Services, 19 October 1954

TO: Director, Ballistic Research Laboratories

1. The dynamic firing test requested has been completed. Firing data and results are contained in Firing Record AR-20352, copies of which are to be forwarded to both Weapons Systems and Terminal Ballistics Laboratories.

2. As pointed out by the D&PS representative at meetings of the Committee on Defense Against Shaped Charges the Picatinny Arsenal Device offers particular promise against non-HEAT rounds. The 90mm AP T33E7 round is the most severe test of the device. At very low remaining velocities (2050 fpr or so), the round was totally defeated four times in four. At 2500 fps or so, the charges provided by TBL were unsuccessful in stopping the round. Since appropriate development testing of this device has been so limited to date D&PS has proposed to test various modifications and applications of this device, particularly against foreign ammunition. Replies from ORDTA, ORDTB, and ORDTT are presently awaited.

3. In view of the SECRET classification of results on this project by Picatinny Arsenal, this correspondence is being upgraded accordingly.

T. F. COLLERAN

COPY OF CONFIDENTIAL OFFICE MEMORANDUM FOR FILE

Mr Kirkpatrick/ccw/22261
2 August 1954

TO : Director, Development & Proof Services

FROM : Director, Ballistic Research Laboratories

SUBJECT: Request for Firing of 90mm Kinetic Energy Rounds and 105mm Recoilless HEAT Rounds

SECRET

1. In connection with work on the defense against shaped charge weapons a method has been proposed by people at Picatiny Arsenal and has been tested to some extent by members of the Terminal Ballistics Laboratory. However, to determine the full value of this type of defense it will be necessary to fire full scale dynamic rounds.

2. This form of defense consists of a line charge, fired by electronic means, to damage the shell before it arrives at the armor. Conversation with Mr. Cronman of TBL indicates that charges are available and that they can be prepared for these tests. It is desirable that the results of these tests be available for the next meeting of the Committee on Defense Against Shaped Charges 26 August 1954.

3. The test desired would consist of 10 rounds of 90mm AP fired into an armor target protected by this device. The other test would consist of 10 rounds of 105mm HEAT ammunition fired from the 105mm recoilless rifle. The armor for this second condition would be identical with that for the first test. It is desired that high-speed motion pictures be made of the terminal effects of these firings.

4. It is requested that 10 rounds each of the kinetic energy and the HEAT rounds be fired. Necessary material and labor will be charged to Project TB3-1224B, W.O. 962-002-00.

5. It is further requested that these Laboratories be notified of the time of the firings in order that an observer may be present.

s/ Herbert R. Dichtenmueller
HERBERT R. DICHTENMUELLER
Lt Col Ord Corps
Asst to Director
BRL

COPY

OFFICE MEMORANDUM - UNITED STATES GOVERNMENT

THRU : Chief, Weapon Systems Laboratory
Chief, Terminal Ballistics Laboratory

ELKirkpatrick/ah/22261

DATE: 3 November 1954

TO : Director, Development and Proof Services

SECRET

FROM : Director, Ballistic Research Laboratories

SUBJECT: Test of HEP vs Line Charge

1. It is requested that 90mm HEP ammunition be fired to determine an effective method of employing the line charge for the defeat of this type of ammunition as per conversations between Mr. E. L. Kirkpatrick of WSL, Mr. Kronman of TBL and Mr. Pillersdorf of D&PS.

2. Twenty-five lot PA 188-8 HEP projectiles will be allocated for these tests under Project TB3-1224B.

3. The line charges with their sensing circuits will be supplied by the TBL of BRL at the time of the tests.

4. It is requested that the armor arrangement for these tests be such that it would be defeated 100% of the time by the 90mm HEP round when a defense mechanism is not used. The arrangement to be used will be with concurrence of TBL, WSL and D&PS representatives.

5. It is requested that spalls resulting from any unsuccessful line charge defenses be recorded with their weight, description and photographs.

6. The tests will be interrupted at any time the BRL deems necessary for revision of the sensing device.

7. It is requested that 10 rounds be fired at a condition before it is credited with successful defeat of the round.

8. It is requested that high speed motion pictures be taken of the engagement of the round with the target.

9. It is requested that photographs be taken of the target arrangement before and after the tests.

10. The results of these tests will be classified "SECRET".

11. It is requested that the BRL be notified at least 72 hours prior to the firing of these tests so that Picatinny Arsenal and the United Shoe Machine Company, under contract to Picatinny Arsenal, may be notified.

12. The priority of this project is 1A.

/s/ E. N. Kirsten
/t/ E. N. Kirsten
Lt. Colonel, Ord Corps
Asst. to Director
Ballistic Research Laboratories

SECRET

17

Mr APillersdorf/hlc/23229

APG(S)471/31
00/4S-18892

ORDBG-DPS-AA

SUBJECT: Dynamic Tests of Picatinny Arsenal Device (Cutting Charge)

TO: Chief of Ordnance
Department of the Army
Washington 25, D. C.

ATTENTION: ORDTT

SECRET

1. The efficacy of the Picatinny Arsenal Device in defeating kinetic energy and HEAT projectiles has been demonstrated by a brief firing test of a modified charge provided by Terminal Ballistics Laboratory, Ballistic Research Laboratories. Detailed results are reported in Aberdeen Proving Ground Firing Record Ar-20352.

2. Given below is a summary of results obtained for the following projectile types when attacked by the modified Picatinny Arsenal Device:

a. Four rounds of 90mm AP T33E7 Shot were unable to penetrate a 4" armor plate at 15° obliquity protected by a cutting charge; the striking velocity was approximately 2050 fps whereas the ballistic limit velocity of the plate alone was approximately 1700 fps.

b. Four rounds of 90mm AP T33E7 Shot fired at approximately 2500 fps were able to completely penetrate the same 4" armor plate protected by a cutting charge.

c. Six rounds of 106mm HEAT ammunition (the T19E11 Shell) fired at approximately 1600 fps were unable to produce penetrations greater than 2" in the armor plate target protected by a cutting charge.

3. Since the 90mm AP projectile was selected as the most severe test projectile for the cutting charge, the potential of this type of device in an improved form should not be overlooked in other respects:

a. For use against HE shell and composite shot (HVAP, AP-DS, etc.) as well as against Soviet AP-HE ammunition.

b. As an equivalent of appreciable armor thickness; while the 90mm AP projectiles fired at 2500 fps were not totally defeated, they may have been upset or degraded so that the actual ballistic limit velocity against the target plate would have been appreciably higher than the limit velocity obtained by firing against an "unguarded" plate.

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ORDBG-DPS-AA
SUBJECT: Dynamic Tests of Picatinny Arsenal Device (Cutting Charge)

SECRET

4. The cutting charges provided for this test had liners of steel for use against the AP projectiles, and of copper for use against the HEAT ammunition. Results of static detonation tests conducted by Terminal Ballistics Laboratory and reported verbally by their representatives show that steel liners in this type of charge cause more severe damage to AP projectiles than do copper liners. Apparently this is because the larger fragments from the steel liner are able to more effectively damage or break up the heavy body of the AP projectiles. Steel liners should also be effective against HEAT ammunition although because of the thin wall of such ammunition copper liners have been found sufficiently effective. Testing of materials to determine what materiel will furnish the optimum liner for effectiveness against all types of attack has of necessity been limited to date but needs to be explored fully to establish definitely the performance which can be expected from cutting charges. Tests of liner materials should include various types of steels, steel-copper bimetallic or amalgam liners, cast iron and possibly titanium as liner materials.

5. Since the referenced test program has been completed, no further testing can be planned until new directives are received.

a. Development and Proof Services has received a copy of a directive from the Detroit Arsenal, the original being in Office, Chief of Ordnance, ORDTT; it is recommended that this directive be forwarded for action by Development and Proof Services.

6. It is recommended that Development and Proof Services be authorized to investigate the following:

a. Defeat of HE, HVAP, AP-DS, and Soviet PA-HE ammunition by cutting charges.

b. Behavior of cutting charges against higher velocity kinetic energy (AP, APC) and HEAT rounds, this to be given high priority.

c. Testing of a cutting charge incorporating desirable features of the "Claymore Device" for anti-personnel use. This would make for a more versatile and logistically desirable item of ammunition: A dual-purpose tank-mounted or hand-carried grenade.

d. Applications of modified forms of the charge as an anti-tank mine and as a device to defeat anti-tank mines.

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ORDTB

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FM CO PICATINNY ARSENAL DOVER NJ

TO CG ABERDEEN PG MD

DA GRNC

FOR ORDBG-AA-DPS PLESS FROM ORDBB-TR1 TT8696 WILLNER SGD CARSON YOUR 22706 AND SUBSEUUENT FONECON BETWEEN PILLERSDORF AND WILLNER CDR DR B A LLOYD AND MR PAUL WILLNER WILL ATTEND TEST FIRINGS 7 DEC 1954 IN CONNECTION WITH TANK DEFENSE PD IN ADDITION A MAXIMUM OF 4 PERSONNEL FROM UNITED SHOE MACHINERY CORP WILL ATTEND IN CONNECTION WITH CONTR P-49

CFN ORDBG-AA-DPS ORDBB-TR1 TT8696 22706 7 1954 4 P-49

03/1856Z

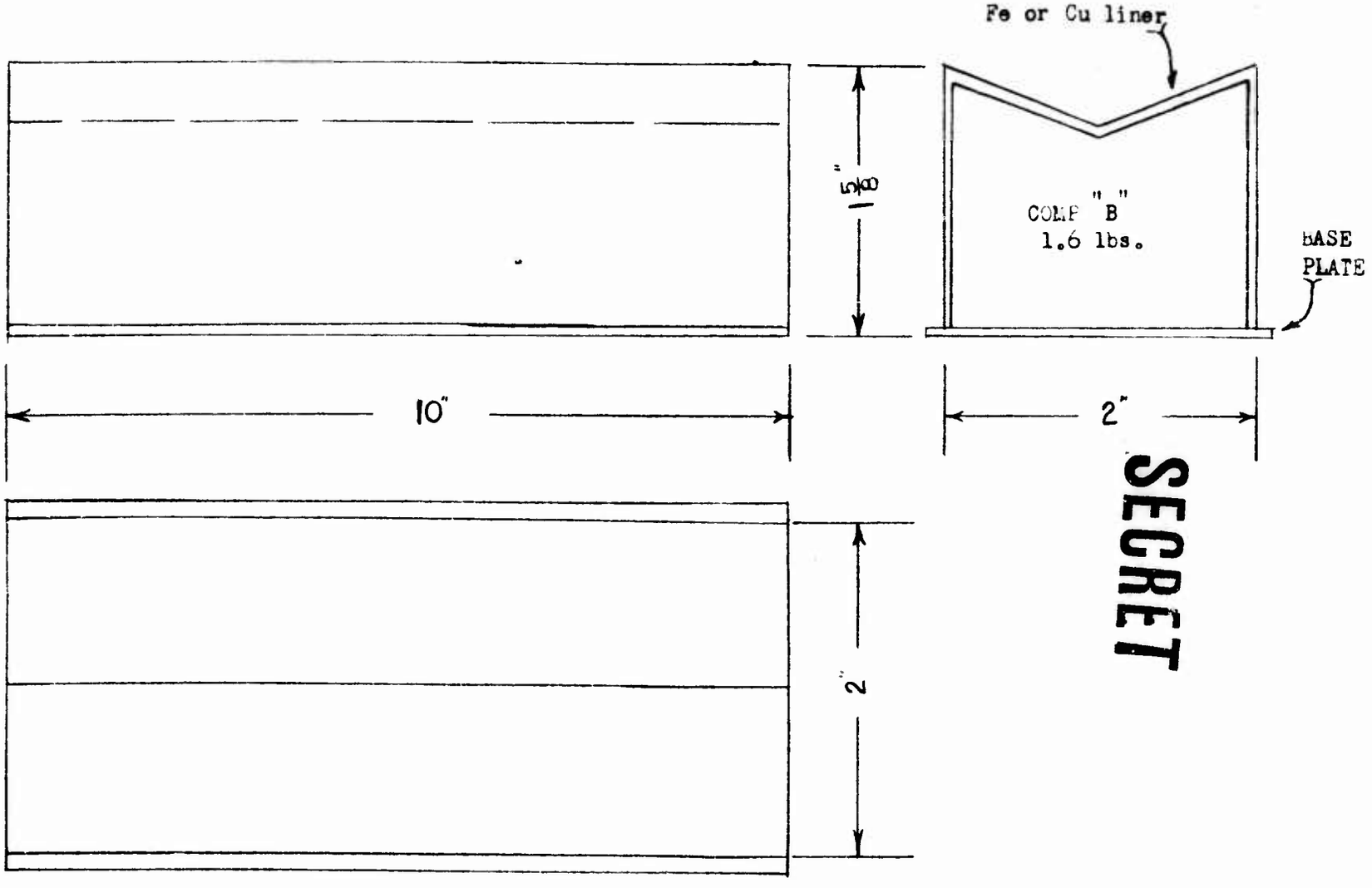
SECRET

APPENDIX B

Sketch of Picatinny Arsenal Device

(Linear Cutting Charge)

PICATINNY ARSENAL DEVICE (LINEAR CUTTING CHARGE)



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APPENDIX C

Firing Record AR-20352

APG/FR
AR-20352

SECRET [redacted]

DEVELOPMENT AND PROOF SERVICES
ABERDEEN PROVING GROUND, MARYLAND
FIRING RECORD

OBJECT OF TEST: To Test The Effectiveness of a Special Picatinny Arsenal Device (Line Charge) in Defeating 90mm AP and 106mm HEAT Ammunition.

FIRING RECORD NO: Ar-20352
SHEET 1 OF 3
DATE OF TEST: 18 August '54 thru 25 August '54

REFERENCE: Memorandum dated 2 August 1954 from Director, BRL, to Director, D&PS

DEVELOPMENT PROJECT NO.: TB3-1224B

SECRET

W. O.: 962-002-00

APG 353.4/1765

MATERIAL

Rolled Homogeneous Armor Plate No. 11424C1, 4" x 65" x 90", 329BHN
Rolled Homogeneous Armor Plate No. 11425A, 4" x 65" x 90", 324BHN

AMMUNITION - Henry, T13

1. Shell, 106mm, HEAT, T119E11 (M344), Ammunition Lot No. PA-E-12356.
2. Shot, 90mm, AP T33E7, Ammunition Lot No. RTQ 1-3.
3. Picatinny Arsenal cutting charge (Line Charge):- Modified charges provided by TBL, BRL. Description: BRL Model 8, loaded with 1.6 pounds of Comp. B; dimensions:-10" long, 2" wide, 1 5/8" high with 140° "vee" shaped slot cut longitudinally into one of the 10" x 2" surfaces. Either a steel (0.062" thick) or copper (0.065" thick) liner was assembled into the slot. See Inclosure No. 3 for a sketch of the Line Charge.

FACILITIES

Gun, 90mm, M3, No. 6171, with Tube No. 2597.
Recoilless Rifle, 106mm, T170E1, No. 166, with Tube No. 6115.

DESCRIPTION OF TEST SETUP

The target armor, a 4" x 65" x 90" RH Armor plate, was leaned against the front of the plate butts, tipped back from the vertical. The Line Charge and triggering screens were then positioned on the ground a few feet in front of the target plate which was some 150 feet from the gun. An M-36 detonator placed in the Line Charge was connected to one of the screens, and the screens energized by putting a 1200 volt D. C. power supply across them. A projectile passing through the screens completed the triggering circuit, setting off the M-36 detonator and the Line Charge. Copper mesh screens were used for the 90mm Shot, while thin aluminum foil strips were used in the screens when firing the sensitive 106mm HEAT shell to avoid fuze initiation.

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RESULTS

1. 90mm AP T33E7 Shot

a. Five rounds of 90mm AP T33E7 Shot were fired against the four inch plate at 15° obliquity. The striking velocity of approximately 2050 fps was some 300 fps above the estimated ballistic limit of the plate. Steel liners were used in all charges tested against the 90mm Shot.

(1) The Line Charge cutting fragments missed the first 90mm round (test round no. 3); the result was a complete penetration of the plate.

(2) Each of the next three rounds (test rounds nos. 4, 5, and 6) was struck by the cutting fragments of the Line Charge and was unable to penetrate the target; a 6" diameter scoop of 1" to 1 1/4" depth was produced by each round.

(3) A smear type photograph (see APG Photo B2167) was made of one round. As shown by the photo, Line Charge fragments have succeeded in breaking the projectile. The entire ogive has been broken off.

b. Four rounds of 90mm AP Shot (test rounds nos. 7, 8, 9, and 10) were fired at a velocity increased to approximately 2500 fps, with the armor at 15° obliquity. Each round made a complete penetration of the target. The effect of the Line Charge fragments on these rounds is unknown since no high speed motion pictures were obtained.

2. 106mm Shell, HEAT, T119E11 (M344)

a. Ten rounds of 106mm recoilless HEAT ammunition were fired at approximately 1600 fps with the target plate at 30° obliquity. Copper liners were used in the Line Charges supplied for this phase.

(1) Six 106mm rounds (test rounds nos. 1, 2, 3, 4, 6, and 7) were evidently struck by the Line Charge fragments; the effect of these on the target consisted, in each case, of fragment gouges and small jet penetrations (0" to 2½") of the armor.

(2) Two rounds (test rounds nos. 5 and 9) apparently were missed by the main fragments of the Line Charge. Each of the two rounds completely penetrated the target and produced residual penetrations of approximately 2" in a vertical back-up armor plate placed eleven feet behind the target.

(3) One round (test round no. 8) evidently was missed by the main fragments of the Line Charge and also failed to function by fuze action. This round detonated during crush-up against the plate without formation of a jet. The sole effect on the target plate was a 7" diameter dent, approximately 1/4" deep.

(4) One calibration round (test round no. 10) was fired without use of the Line Charge. It failed to function by fuze action and detonated during crush-up without formation of a jet. Results were identical to those of Round 8.

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FIRING RECORD NO. Ar-20352
SHEET 3 OF 3

DETAILED RESULTS OF TEST

Inclosure 2 provides round-by-round firing data and results.

OBSERVERS

Other than BRL and D&PS personnel conducting the test, no observers were present.

APPROVED:

BENJAMIN S. GOODWIN
Chief, Arms & Ammunition

W. C. PLESS
Chief, Armor Branch

J. C. GILLETT
Lt., Ord Corps
Proof Officer

INCLOSURES:
1. Distribution
2. Firing Data
3. Description of Triggering System & Line Charge Sketch
4. APG Photos B2054, B2055, B2167

SECRET

FIRING RECORD NO. At-20352
INCLOSURE 1

DISTRIBUTION

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FIRING DATA

90mm AP T33E7 SHOT

Test Setup: Target plate No. 1142C1; gun to target distance of approximately 150 feet; Line Charges with steel liners.

Date & Rd. No.	Distance--Screens to Plate	Distance--Line Charge to Plate	Distance--Line Charge is below line/flight of projectile	Distance--Line Charge Center is off-center from line/flight of projectile	Results (All dimensions of plate damage given as height by width.)
18 August Rd 1	Conditioning Round				Complete penetration of plate: face: scoop, 7" x 5¾"; back: exit hole, 9" x 8½"; 100% back spall. Plate obliquity: 14°; Striking velocity: 2001 fps.
18 August Rd. 2	Conditioning Round				Partial penetration of plate: face: scoop, 10" x 6¼", 3½" deep; back: Bulge, 10⅛" x 9⅛" with 20" circular crack around upper bulge circumference. Plate obliquity: 30° Striking Velocity 2085 fps
18 August Rd. 3	39 3/4"	35 1/4"	18"	4"	High speed motion pictures indicate Line Charge missed projectile. Complete penetration of plate: face: crater, 6" x 6"; back: exit hole, 8" x 9 1/4"; 100% back spall Plate obliquity 15°; Striking velocity: 2085 fps.
19 August Rd. 4	39"	42"	18"	4"	Projectile hit by Line Charge. Partial penetration of plate: face: scoop, 6" x 6", 1¼" deep; back: slight bulge, 4" diameter. Plate obliquity: 15°; Striking Velocity 2026 fps.

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19 August Rd. 5	39"	41"	18"	4"	Results identical with round four. Plate obliquity: 15°; Striking Velocity: 2070 fps.
19 August Rd. 6	84"	86 1/2"	18"	4"	Results identical with round four. Plate obliquity: 15° Striking velocity: 2060 fps.
19 August Rd. 7	84"	86 1/2"	18"	4"	Line Charge effect on projectile unknown. Complete penetration of plate: face: crater, 7" x 7" rear: exit hole, 11" x 12⅛"; 100% back spall. Plate obliquity: 15°; Striking Velocity: 2485 fps.
19 August Rd. 8	40"	40"	18"	4"	Complete penetration of plate: face: crater, 6 1/2" x 6 1/2" back: exit hole, 8 1/4" x 9 1/2"; 95% back spall. Plate obliquity: 15°; Striking Velocity: 2489 fps.
20 August Rd. 9	40"	44"	12"	4"	Complete penetration of plate: face: crater, 7" x 6¼" rear: exit hole, 6" x 4½"; 10% back spall. Plate obliquity: 15°, Striking Velocity: 2495 fps.
20 August Rd. 10	40"	47"	12"	4"	Complete penetration of plate: face: crater, 7" x 6⅛" rear: exit hole, 8 ¾" x 9 ¾"; 10[redacted] back spall. Plate obliquity: 15°; Striking Velocity: 2496 fps.

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20 August Rd. 11	28'	28' 3"	18"	"

This round fired with target set back to obtain "smear type" photograph. Striking Velocity 2107 fps. Camera indicates that the projectile nose was fractured by fragments of line charge (see APG photo B2167). See APG photo B2055 for effect of fragments on the target plate.

NOTE: Several rounds of 90mm AP T33E7 Shot were fired in an attempt to obtain the ballistic limit, at 15° obliquity, of plate 11424C1. This attempt was discontinued, however, after the velocity had been dropped to 1792 fps and complete penetrations were still being achieved. The data gained from this firing substantiated the assumption made during initial firing of this program that velocity levels of 2000 fps or higher would be well above the plate BL.

SECRET

BL TEST- 13 September 1954

Round No.	Striking Velocity	Result
1	1759 fps	Complete Penetration
2	1688 "	" "
3	1709 "	" "
4	1592 "	" "

SECRET

FIRING DATA

106mm Shell, HEAT, T119E11 (M344)

Test Setup: Target plate No. 11425A; gun to target distance of approximately 156 feet; Striking Velocity of approximately 1600 fps; plate obliquity of 30°; Line Charges with copper liner.

Date & Rd. No.	Distance--Screens to Plate	Distance--Line Charge to Plate	Distance--Line Charge is below line/flight of projectile	Distance--Line Charge Center is off-center from line/flight of projectile	Results
23 August Rd. 1	40"	50"	18"	4"	Line Charge evidently hit projectile; only 2½" * penetration, with jet hole badly deformed. No slug in plate. Jet was deflected several inches away from aiming point and entered plate at an upward angle rather than in a horizontal direction.

* Probe depth

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[redacted]

30

Firing Data, [redacted] (Cont'd) Cont

24 August Rd. 2	20"	30"	18"	4"	Results same as Round 1.
24 August Rd. 3	20"	30"	18"	4"	Line Charge evidently hit projectile: No gouges or jet holes, only explosive blast marks on armor plate face. Zero penetration.
24 August Rd. 4	18"	23"	18"	4"	Line Charge evidently hit projectile: A few shell fragment gouges centered about the aiming point in a vertical pattern, but no jet hole in plate.. Zero penetration.
24 August Rd. 5	24"	31"	40"	12"	Line Charge evidently missed projectile: complete penetration of target plate plus [redacted] penetration into the vertical backup armor plate 11 feet behind target plate.
25 August Rd. 6	19"	22"	29"	6"	Line Charge evidently hit projectile: only a few shell fragment gouges arranged in a vertical pattern centered about the aiming point on the plate. (See APG Photo B2054). No jet hole. Zero penetration.
25 August Rd. 7	22"	23"	42"	9"	Results same as for Round 6.
25 August Rd. 8	27"	25½"	46"	71" NOTE: Line Charge placed 71" to left of line/flight and then tipped so a perpendicular thru its mid-point intersected line/flight.	Line Charge effect on projectile unknown. Damage to plate consisted of a 7" diameter dent approximately ½" deep on front face, slight bulge on rear face. No gouges. Apparently round failed to function by fuse action, detonating upon crush-up against the target--no jet formed.

[redacted]

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Firing Data [redacted] (M344) Cont

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25 August Rd. 9	19"	19"	18"	NOTE: Line Charge placed 54" to left of line/flight and then tilted so a perpendicular thru its mid-point intersected the line/flight.	Line Charge evidently missed projectile; a complete penetration of the target armor plus a 2" penetration into the vertical back-up plate located 11 feet behind the target plate.
25 August Rd. 10	No Line Charge - Calibration Round				Round failed to function by fuze action at instant of impact, and was detonated during crush-up against the plate. With cone crushed, no jet formed. Effect on plate was identical with Round eight.

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DESCRIPTION OF TRIGGERING SYSTEM

Schematic of BRL(TBL) Triggering System for Initiating Modified Picatinny Arsenal Device

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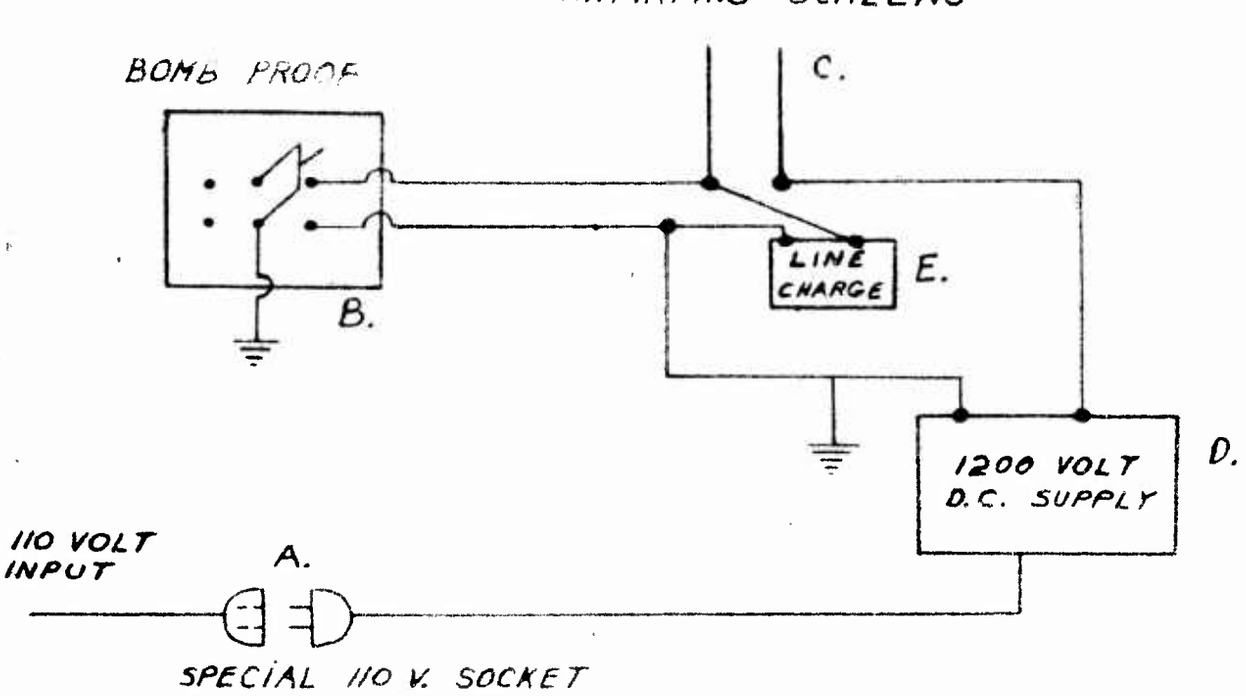
1. Schematic Diagram:



2. Safety Features:

A. A special connecting socket for 110 V input kept by demolition man until he is in shelter.

B. DPDT switch in insulated box, closed and shorted to ground in personnel bombproof (switch opened just prior to firing when all personnel are under cover).

2. Safety Features: continued

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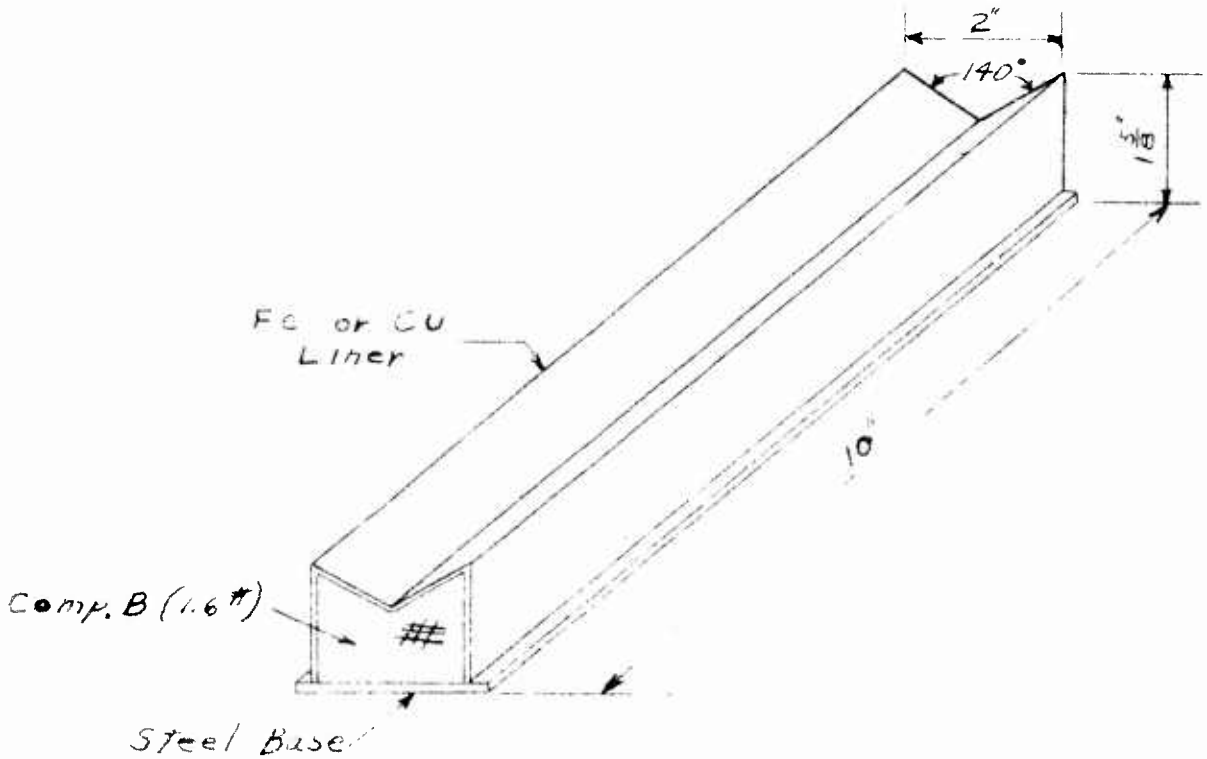
C. Screens checked for infinite resistance to 6000 volts.

D. Power supply shorted to ground prior to firing; unshorted before each firing; shorted after each firing.

E. M36 detonator installed by demolition man in usual manner (leads attached, then M36 inserted into booster through hole in supporting plate for charge).

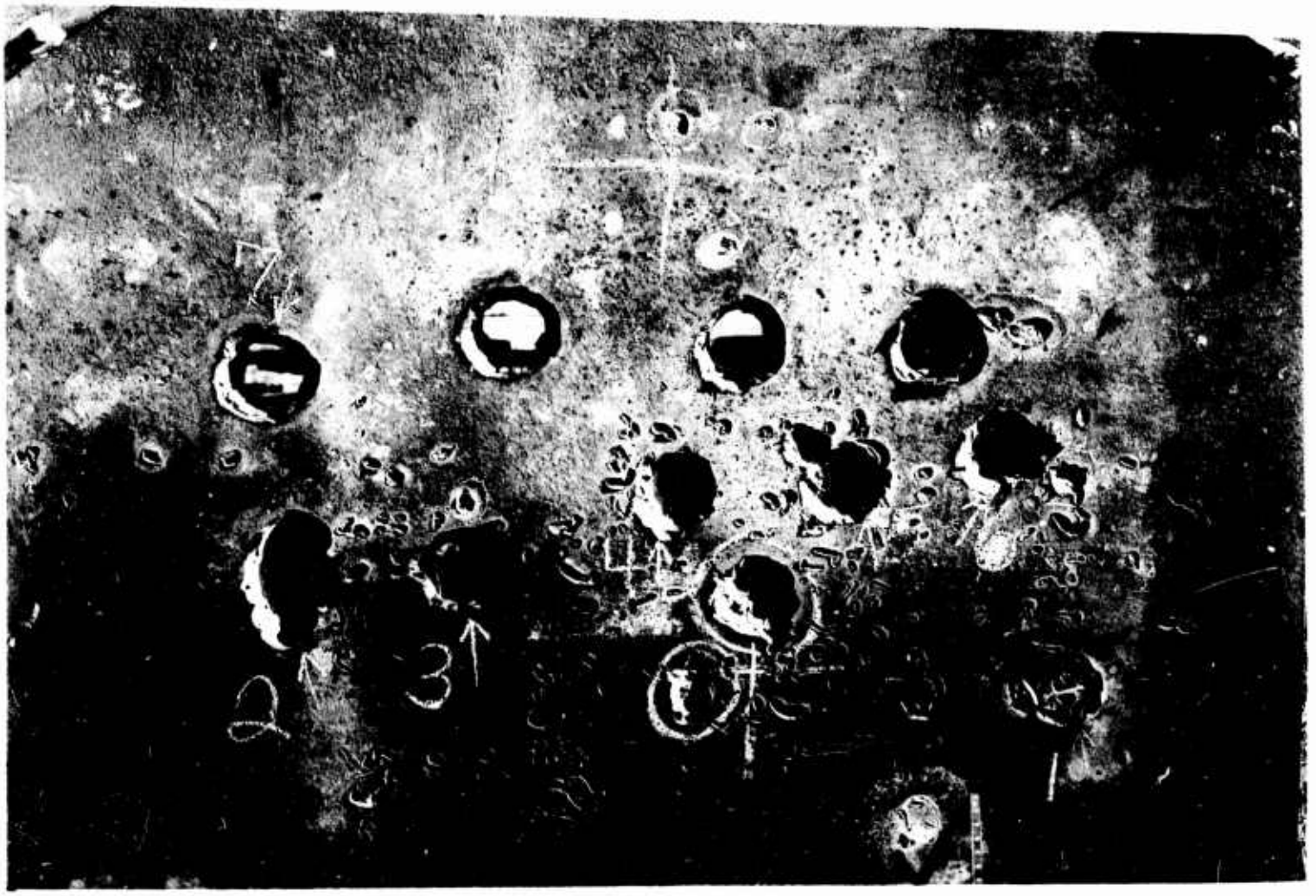
- - - -

SKETCH OF LINE CHARGE



B2054 CONFIDENTIAL § ABERDEEN PROVING GROUND § 13 September 1954

Project No. TB3-1224B. Testing of Special Picatinny Arsenal Device. Front view of the 4" target plate used during the test of the Picatinny Arsenal Device versus the Shell, 106mm, HEAT, T119E11 (M344). Ten rounds were fired; rounds 3 and 4 are not marked since only negligible scarring resulted from these rounds.



B2055 CONFIDENTIAL § ABERDEEN PROVING GROUND § 13 September 1954

Project No. TB3-1224B. Testing of Special Picatinny Arsenal Device. Front view of the 4" target plate used during the test of the Picatinny Arsenal Device versue the 90mm APT 33E7 Shot. Eleven rounds were fired. Rounds 1 and 2 were fired without use of the Picatinny Device. Round 11, badly broken before striking the plate, is indicated by the circled areas.

CONFIDENTIAL

B2167 CONFIDENTIAL § ABERDEEN PROVING GROUND § 20 August 1954

Project No. TB3-1224B. Test of Special Picatinny Arsenal Device. Shot, 90mm, AP, T33E7 (Round No. 11), broken in flight by fragments of modified cutting charge.

SECRET

APPENDIX D

FIRING DATA - PAD VS 90LM HEP-T

FIRING DATA - PAD VS 90MM HEP

RD. NO. SV(fps)	TRIGGER SCREEN DIST. TO PLATE	RESULT ON PLATE	DIST. PAD BELOW PROJ (Z)	DIST. PAD OFF-SET FROM L OF FLIGHT	DIST. PAD TO PLATE	PAD LINER ANGLE
1 Not Meas.	None Used	Spall	No PAD	-	-	-**
2	None Used	Spall	No PAD	-	-	-**
3	Al.Mesh 30"	No Spall	18"	4"	32"	140°
4 2332	Al.Mesh 30"	No Spall	30"	6"	32"	140°
5 2331	Al.Foil 30"	Spall	60"	10"	32"	140°
6 2336	Al.Foil 30"	Spall	60"	10"	32"	140°
7 2334	Cu.Mesh 30"	Spall	45"	6"	32"	140°
8 2358	Cu.Mesh 30"	Spall	45"	6"	30"	115°
9 2361	Cu.Mesh 30"	Spall	45"	6"	30"	-***
10 2349	Cu.Mesh 43"	Spall	30"	6"	47"	165°
11*	Cu.Mesh 30"	No Spall	18"	6"	32"	115°
12*	Cu.Mesh 30"	No Spall	30"	6"	32"	140°
13*	Cu.Mesh 30"	Spall	45"	6"	32"	140°
14*	Cu.Mesh 30"	No Spall	30"	6"	32"	115°
15*	Cu.Mesh 30.5 ft	No Spall	30"	6"	30.6 ft	140° #
16*	Cu.Mesh 30.5 ft	Spall	45"	6"	30.6 ft	140°
17 2020	Cu.Mesh 30"	Spall	45"	6"	32"	140°

SECRET

FIRING DATA - PAD VS 90MM HEP (CONT'D)

SECRET

RD. NO. SV (fps)	TRIGGER SCREEN DIST. TO PLATE	RESULT ON PLATE	DIST. PAD BELOW PROJ (Z)	DIST. PAD OFF-SET FROM L OF FLIGHT	DIST. PAD TO PLATE	PAD LINER ANGLE
18 2320	Cu. Mesh 46"	Spall	45"	6"	34"	140°
19	Cu. Mesh 34 ft.	Spall	45"	6"	34 ft	140° ##

* Velocities not measured. Estimated: 2320-2340 fps.
** Calibration of Ammunition
*** PAD not initiated
# Fastax films taken
Missed screen

SECRET

APPENDIX E

FASTAX FILM AND WITNESS PLATE TRIALS

I. PHASE I

A. PURPOSE

To obtain fragment velocity and penetration data, using mild steel target witness plates.

SECRET

B. AMMUNITION

Two pads with 140° copper liners. No. 1 was statically detonated with base parallel to ground, mild steel laminate 66 inches overhead. Laminate consisted of two 12 gauge sheets followed by 1/4 inch sheets. No. 2 was detonated with base perpendicular, in longitudinal direction (B), target 66 inches away. Both charges were photographed by Fastax camera to obtain fragment velocity data.

C. PADS 3 and 4

115 degree liners, detonated like No. 2 except that laminate of witness sheets consisted of one 12 gauge mild steel sheet followed by 1/4 inch mild steel sheets. These charges were detonated for fragment distribution data. (See Plots 1,2, and 3). Pad No. 4 was modified to simulate combat conditions as follows: The liner trough or wedge angle was filled with moist soil scraped in the test area. This dirt filler was held in place by masking tape. The charge was detonated against the same setup as was No. 3. A summary of fragment penetration and distribution data is given in Plots 1,2, and 3.

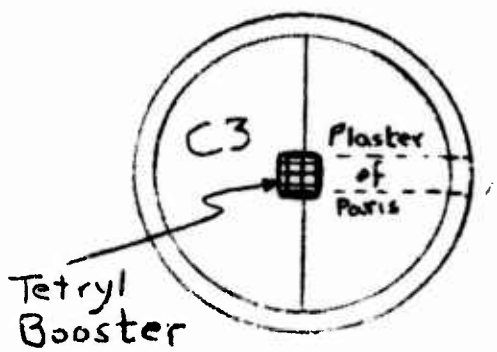
II. PHASE II FRAGMENTATION CALIBRATION

A. PURPOSE

To obtain an indication of PAD fragmentation efficiency and penetration capabilities by comparison with available devices using lesser weights of explosive.

B. PROCEDURE

Two 2 inch I.D. black pipe nipples and four 2 1/2 inch I.D. galvanized pipe nipples were capped at one end. Each was then filled lengthwise with an inert mixture (Plaster of Paris) for one half of the nipple diameter, looking in section like this:



The plaster filling was then drilled thru, at the center of the nipple length, for a tetryl booster pellet. The remaining semi-circular section was then filled with explosive C3. A tabulation of the pipe charge characteristics follows:

C. PIPE CHARGE DATA

SECRET

Pipe ID	2 inches	2 1/2 inches
Pipe OD	2 3/16 inches	2 13/16 inches
Pipe Length	6 inches	10 inches
Pipe Type	Black	Galvanized
Wt Charge	.53 ±.03 lb C3	1.3 lbs C3
Wt Pipe, two Steel Caps (at ends) & Inert Load	4.75 lbs	10.2 lbs
Wt of Single Cap	1.15 lbs	2.15 lbs
Wt as fired w/one cap	5.3 ±.10 lbs	9.3 ±.10 lbs

D. RESULTS

1. When the 2 inch pipe nipple was detonated from a position with its axis parallel to the ground, the fragment pattern obtained was apparently too limited to be comparable to a PAD. The next charge used was the larger diameter, longer, 2 1/2 inch I.D. nipple. This charge, effectively a miniature bangalore torpedo, was detonated with the axis perpendicular to the ground. The large angle of fragment distribution is apparent from APG photographs B5971-73. This pattern might be considered inherent in the shape of the charge casing. Also noteworthy are; reduction in numbers of fragments for the thick steel pipe casings and greater proportion of penetrating fragments in later witness sheet (No.3).

2. A tabulation of fragmentation data for the first of each type of pipe nipple and the four PADS detonated in the last phase of this program is given below. Two additional pipe nipples of each type (2 inch I.D. and 2 1/2 inch I.D.) were detonated with axis vertical. Fragmentation data, density, and numbers of indentations in each mild steel witness sheet are summarized in Plots 1, 2, and 3 which follow.

MILD STEEL WITNESS PLATE FIRINGS

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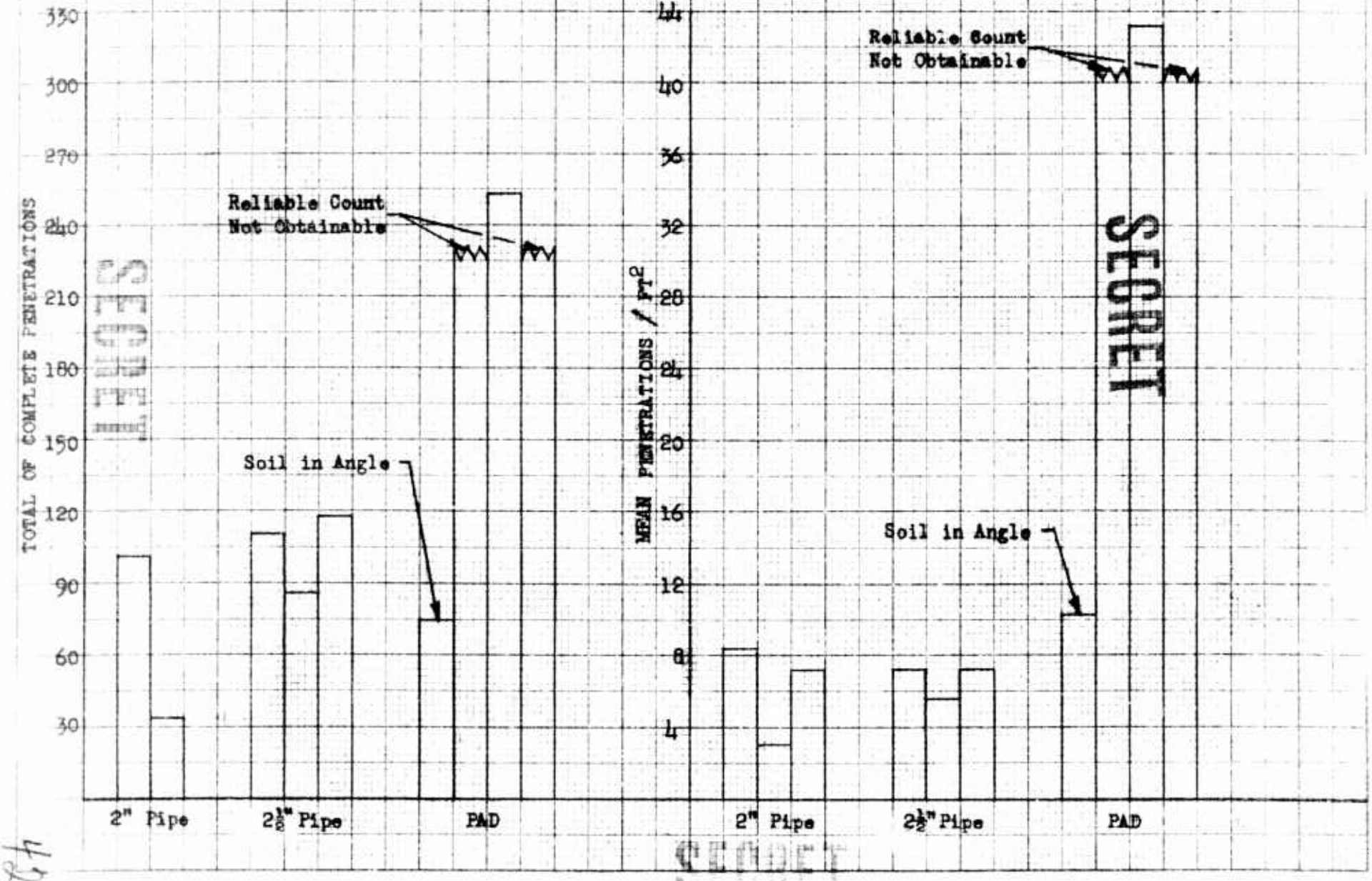
CHARGE	WITNESS PLATES	SPREAD(") OF INDENTATIONS VERT.	SPREAD(") OF INDENTATIONS HOR.	SPREAD(") OF PENETRATIONS VERT.	SPREAD(") OF PENETRATIONS HOR.	TOTAL NO. OF INDENTATIONS	TOTAL NO. OF PENETRATIONS	DENSITY OF INDENTATIONS	DENSITY OF PENETRATIONS
PAD #1	10 ga	10	51	10-14	51	Large areas of tiny & large		Too high to count	
140° Liner	12 ga	10	51	6	32	117	23	.23/ft^2	.12/ft^2
	1/4"	8	42	6	23	65	6	.20	.04
	1/4"	8	35	-	23	34	4	.12	-
PAD #2						Very			
140° Liner	12 ga	21	40	21	40	Large	25.3	-	.30
	12 ga	21	40	21	40	"	60	-	.07
	1/4"	21	40	16	29	164	5	.20	.01
	1/4"	30	36	-	-	13	1	.02	-
STEEL PIPE NIPPLES									
Pipe #1	12 ga	36 ≠	14	36 ≠	14	-	25	-	7.12
2" ID	12 ga	36 ≠	14	36 ≠	14	51	10	.10	.02
Axis at 0° elev.	1/4"	36 ≠	14	-	-	16	-	.03	-
Pipe #2			Over		Over				
2 1/2" ID	12 ga	24	8 ft	24	8 ft	Large	118	Large	7.08
Axis at	1/4"	24	"	-	83"		5	9.34	
90° elev.	1/4"	24	"	-	-		1	3.06	
PAD #3	12 ga		48	15	55	Very Large		-	-
115° Liner	1/4"	27	48	12	55	"	16	21.3	1.7
	1/4"	15	41	-	-	41	-	9.6	-
	1/4"	12	41	-	-	19	-	5.5	-
PAD #4	12 ga	30	35	30	35	Large	Approx. 75	Large	10.26
115° Liner*	1/4"	30	35	0	20	2.08	2	28.5	-
	1/4"	24	32	-	-	13	-	2.4	-
	1/4"	Center of Plate				2	-	-	-

* Sandy loam loosely held in wedge by masking tape.

SECRET

PLOT NO. 1 – FRAGMENT DISTRIBUTION IN FIRST SHEET (12 GA., MILD STEEL)
OF WITNESS PLATE LAMINATE



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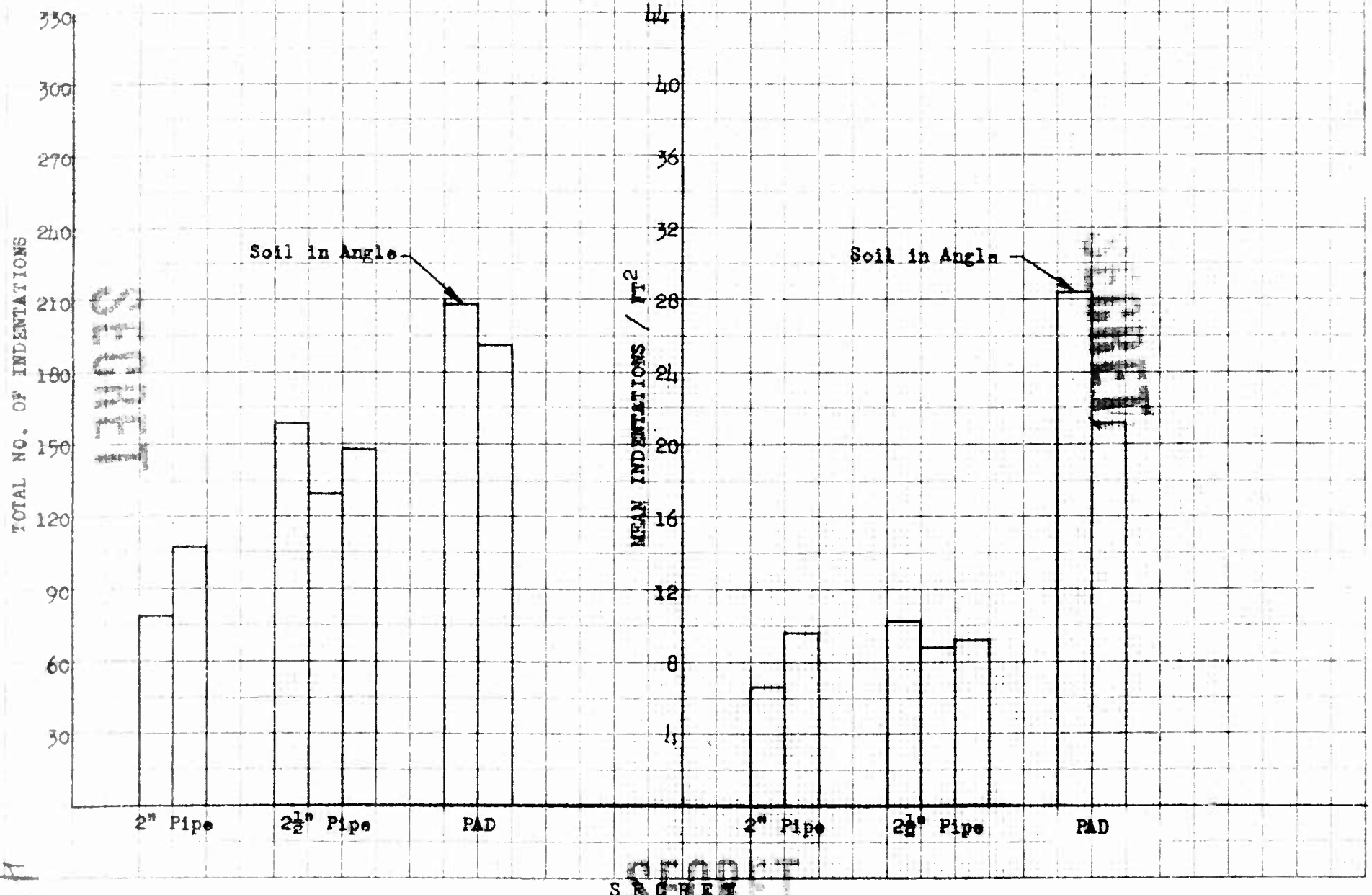
PLOT NO. 2 - FRAGMENT DISTRIBUTION IN SECOND SHEET ($\frac{1}{4}$", MILD STEEL)

OF WITNESS PLATE LAMINATE



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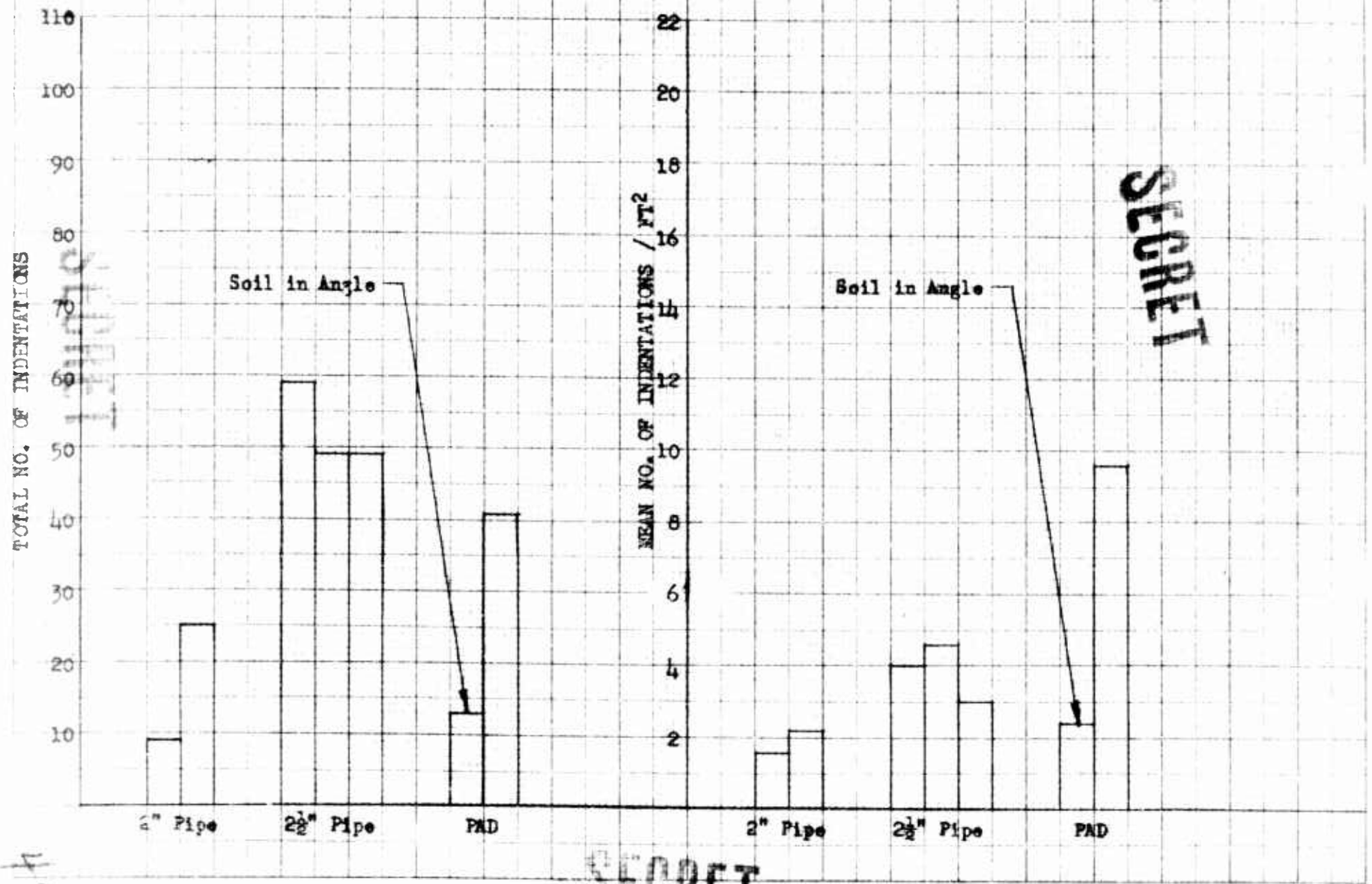
PLOT NO. 3 - FRAGMENT DISTRIBUTION IN THIRD SHEET (¼", MILD STEEL)
OF WITNESS PLATE LAMINATE



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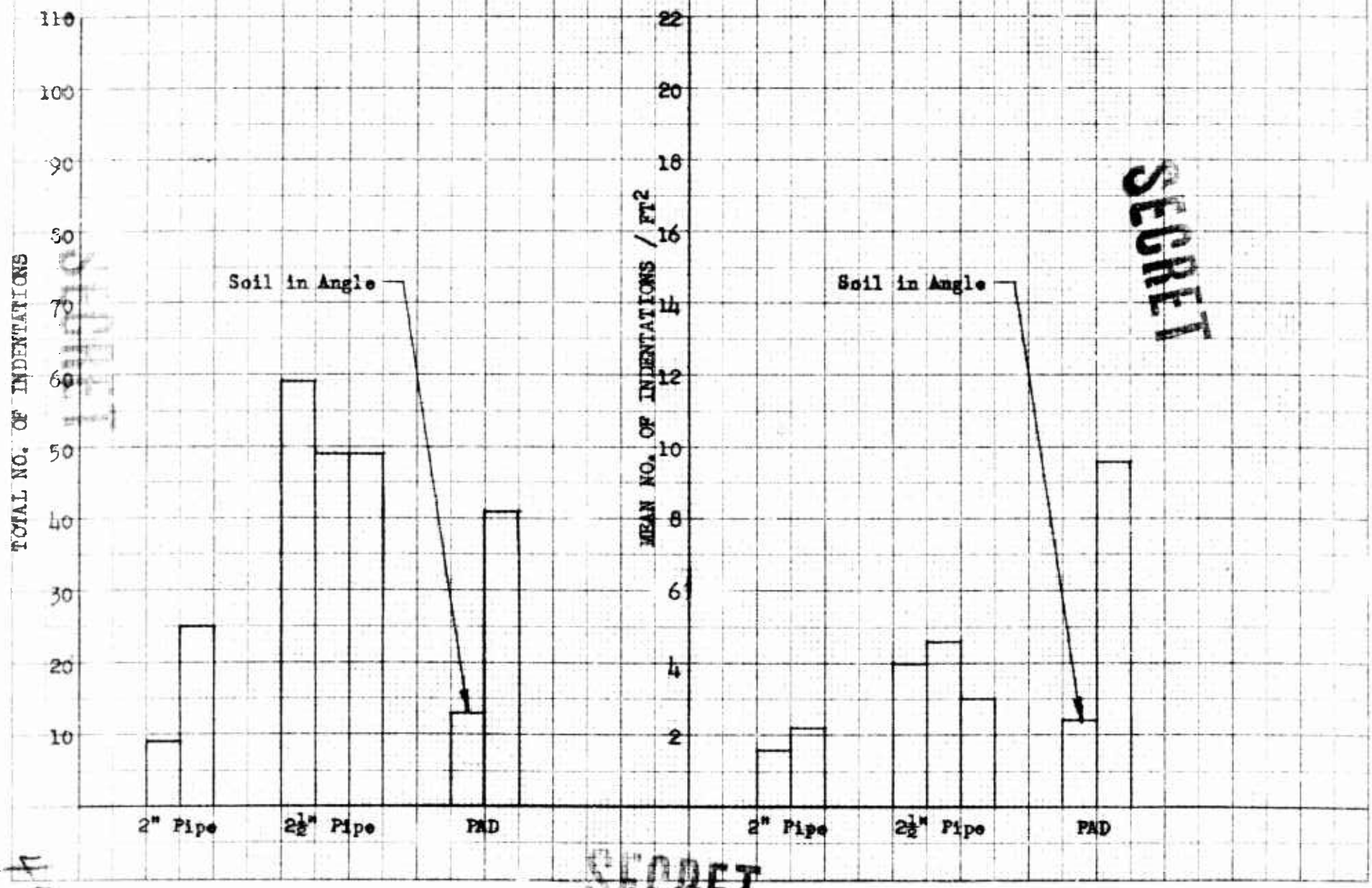
PLOT NO. 3 - FRAGMENT DISTRIBUTION IN THIRD SHEET ($\frac{1}{4}$", MILD STEEL)

OF WITNESS PLATE LAMINATE



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APPENDIX F

APG PHOTOGRAPHS NOS. B5968 THRU B5973

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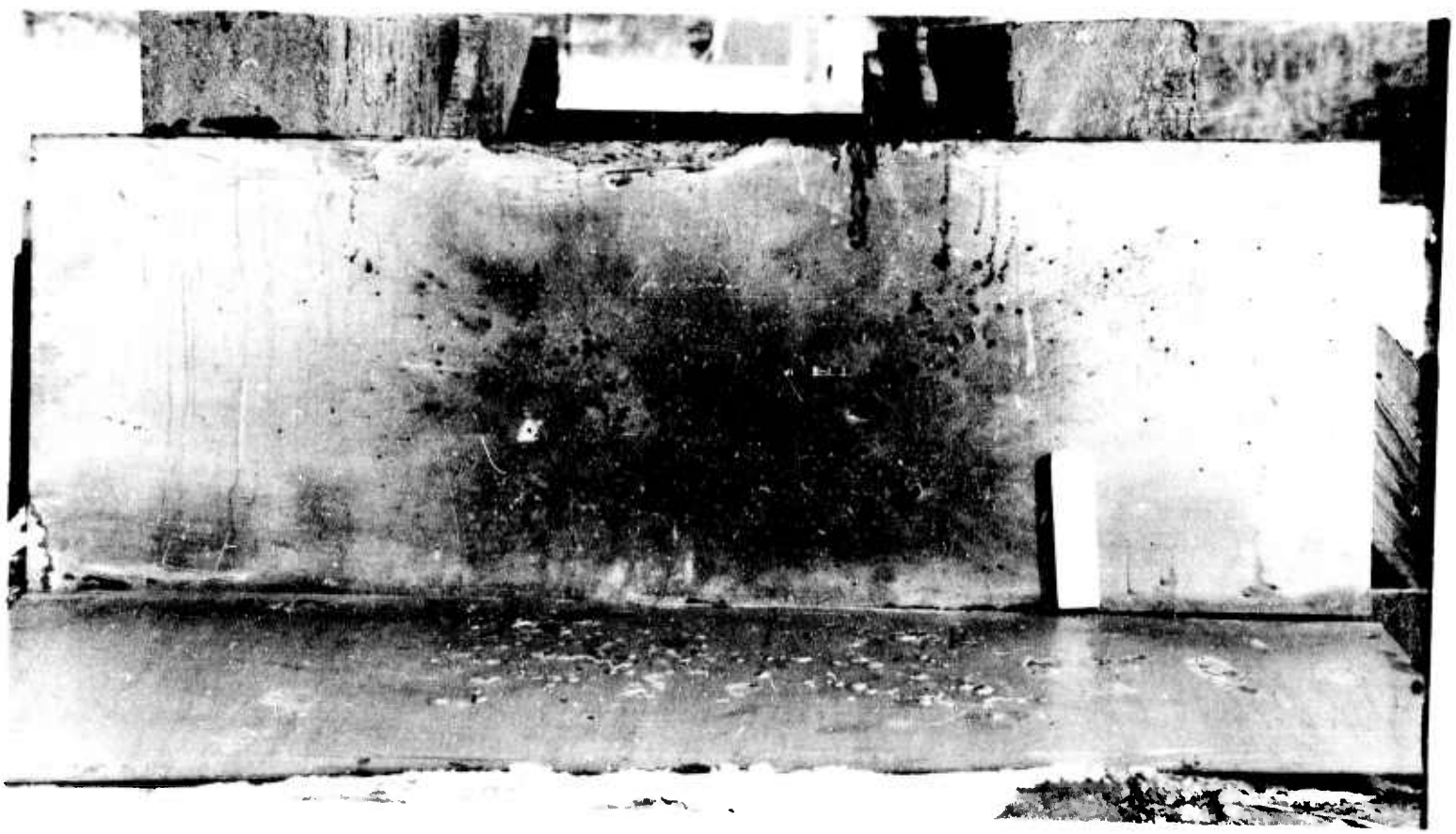


B5968 SECRET ABERDEEN PROVING GROUND 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

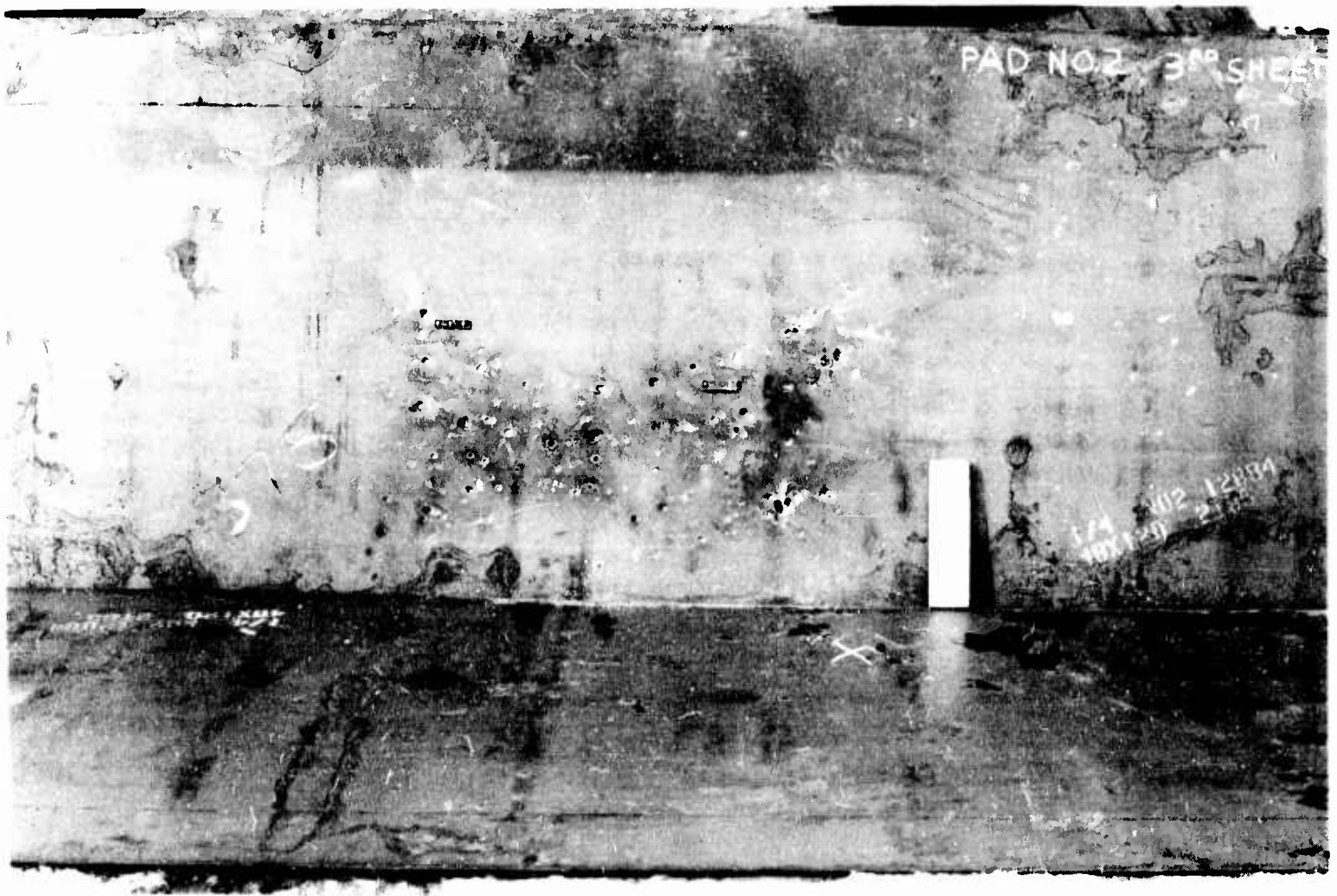
Pad No. 2. Fragment damage 66" from charge in first sheet (12 ga.) of witness plate laminate.

SECRET

B5969 SECRET ABERDEEN PROVING GROUND 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

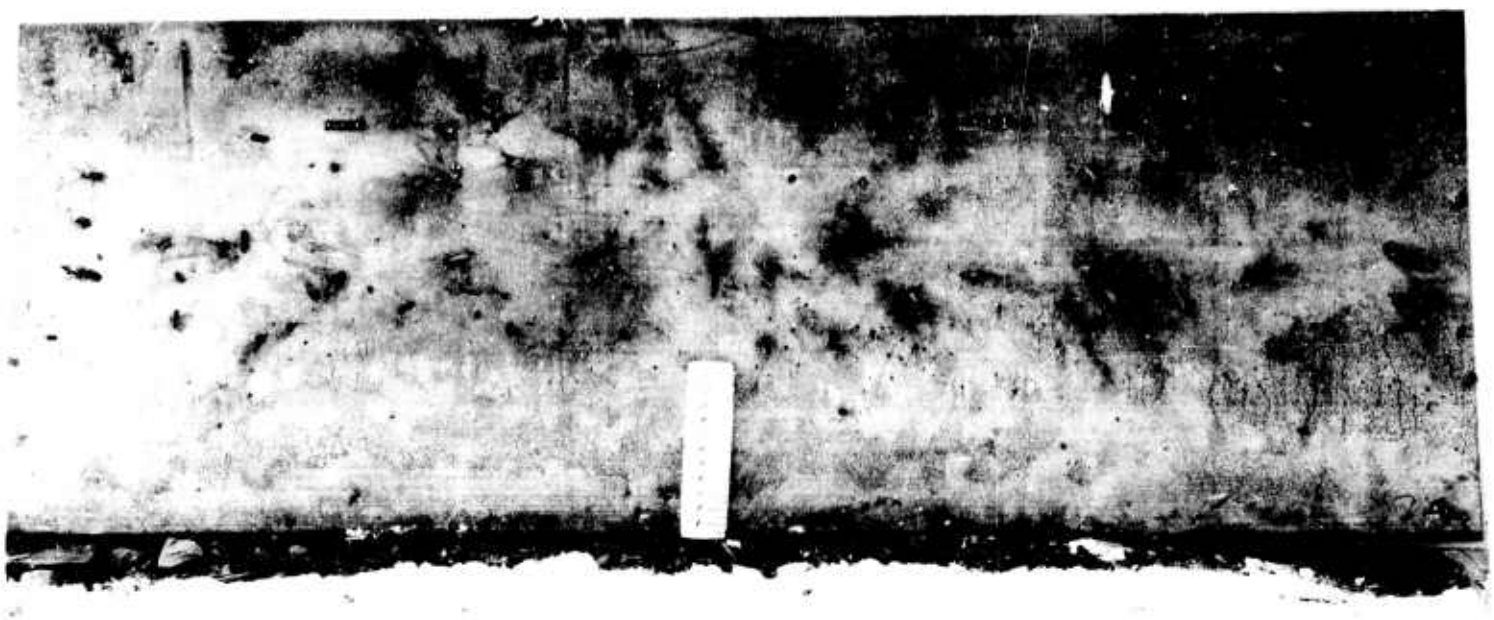
Pad No. 2. Fragment damage 66" from charge in second sheet (12 ga.) of witness plate laminate.



Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Pad No. 2. Fragment damage 66" from charge in third sheet (1/4") of witness plate laminate.

SECRET



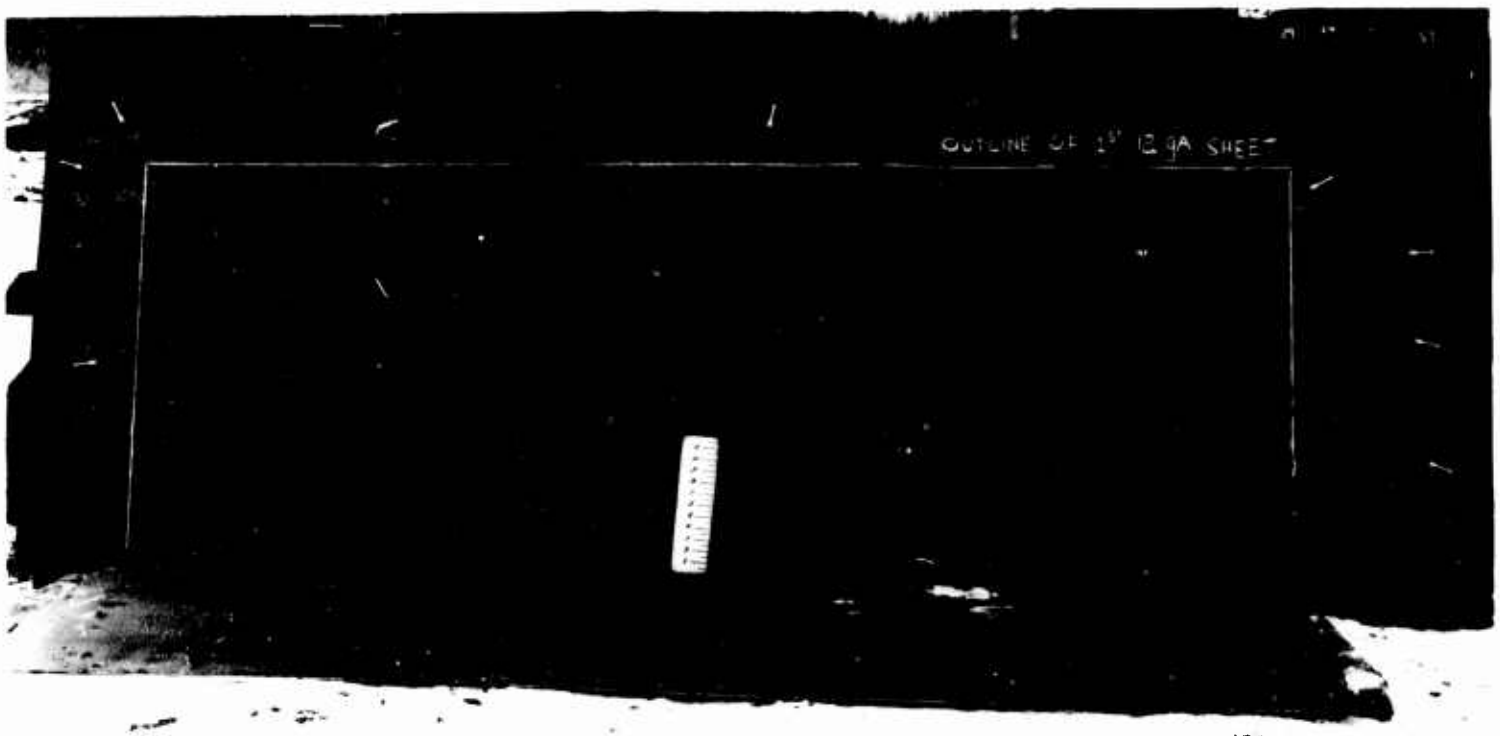
SECRET

B5971 SECRET § ABERDEEN PROVING GROUND § 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

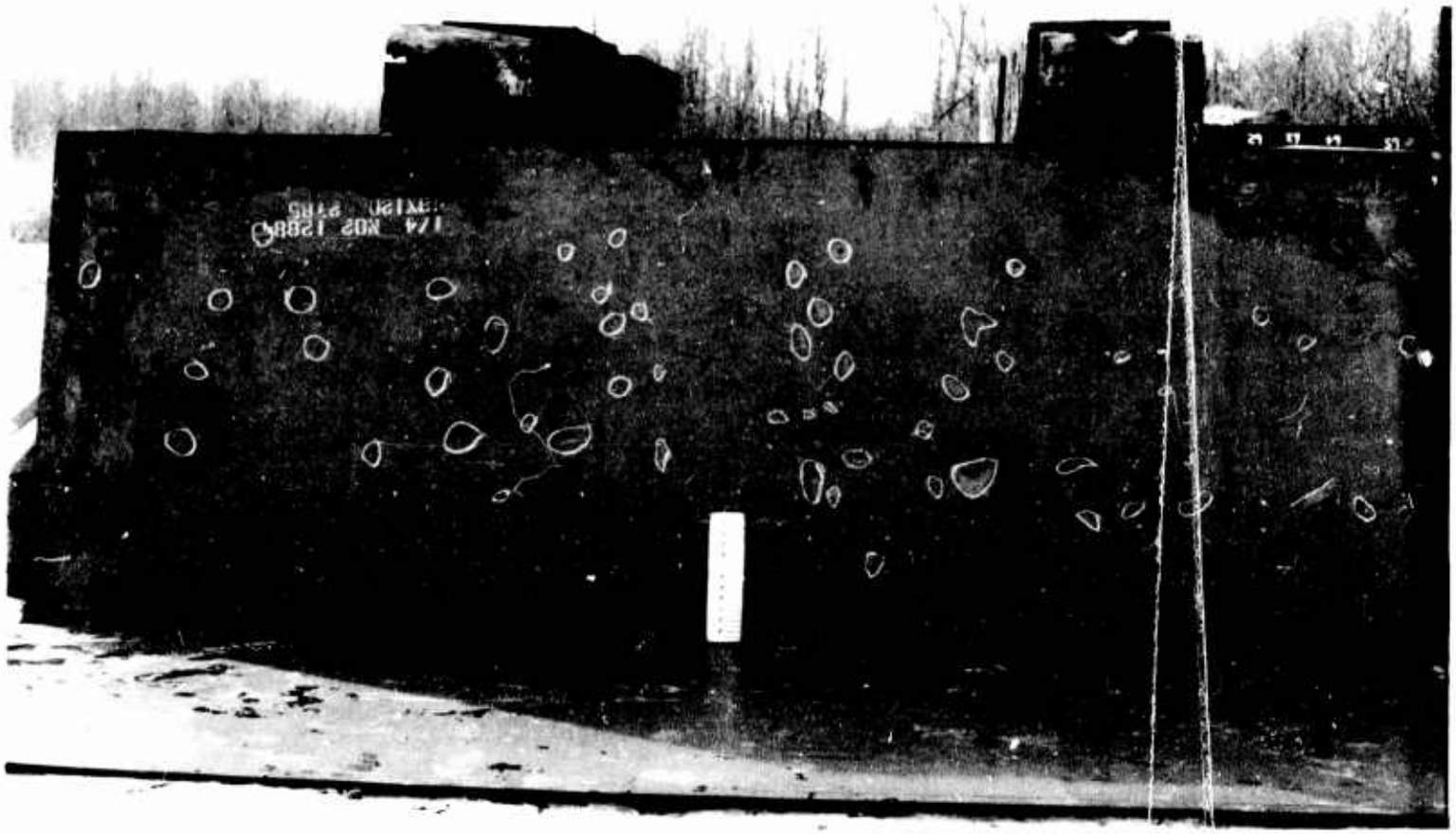
Special Device No. 2. Fragment damage 66" from charge in first sheet (12 ga.) of witness plate laminate.

SECRET



Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.
Special Device No. 2. Fragment damage 66" from charge in second sheet (1/4") of witness plate laminate.

SECRET



B5973 SECRET § ABERDEEN PROVING GROUND § 24 January 1955

Project No. TB3-1224B. Test of Picatinny Arsenal Device (Pad). Penetration into Mild Steel.

Special Device No. 2. Fragment damage 66" from charge in third sheet (1/4") of witness plate laminate.

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